BC

Ministry of Environment and Parks

WESTERN AND NORTHERN CANADA ACID DEPOSITION TRAP ACTIVITIES

ANNUAL REPORT 1986

A report on monitoring and research studies related to acid rain and long-range transport of atmospheric pollutants in Western and Northern Canada

Alberta

ENVIRONMENT

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WESTERN AND NORTHERN CANADA ACID DEPOSITION/LRTAP ACTIVITIES

ANNUAL REPORT 1986

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prepared by the Technical Committee for the Long-Range Transport of Atmospheric Pollutants in Western and Northern Canada

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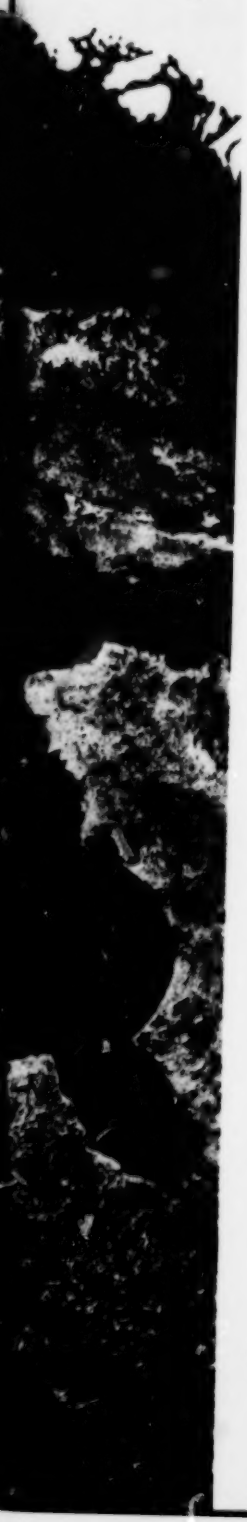
ALASKA
YUKON
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA

MAP OF WESTERN AND NORTHERN CANADA



Map of Western and Northern Canada

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1. INTRODUCTION

Historical Background

On September 4, 1980, deputy ministers and senior officials from Environment Canada and the environment ministries of British Columbia, Alberta, Saskatchewan, and Manitoba, met in Edmonton to review the available information on acid deposition and long-range transport of air pollutants (LRTAP) in Western Canada. They concluded that acid deposition was not a serious problem in the West. But, because of an increase in industrial activity in Western Canada and in the Western United States, they agreed that surveillance of LRTAP and acid deposition was warranted. They established a Consultative Committee of deputy ministers and a Technical Committee of senior officials from the four western provinces and Environment Canada to coordinate monitoring, research, and other activities related to acid rain and LRTAP.

In December 1982, the Committees, which by then included representatives from the Northwest Territories, launched a three-year research program to identify current conditions in Western Canada and provide the information necessary to develop management strategies.

The first three years of coordinated research have satisfied many of the initial goals for Western and Northern Canada, and have provided insights relating to areas which require additional work in support of a sound management strategy.

Significant developments emerging from the first years of research include:

1. Precipitation Monitoring
   - an understanding of the wet deposition levels experienced in Western and Northern Canada;
   - recognition of the confounding effects of dust in precipitation samplers on measurements of acid deposition levels.
2. Sensitivity Maps
   - significant expansion of the water and soil chemistry data bases in Western and Northern Canada;
   - the incorporation of soil data and water data into acid deposition sensitivity maps.
3. Transport/Deposition Models
   - recognition that the mesoscale transport (medium-range transport of air pollutants) is more significant than the long-range transport of air pollutants (LRTAP) in Western and Northern Canada;
   - special review of medium-range transport models;
   - workshop on the models for medium-range transport models.

Research and Monitoring — New Priorities

In September 1985, the same agencies signed a new agreement covering research and monitoring activities from 1985 to 1988. This new agreement builds on the successful conclusion of the first three years of coordinated research.

The new priorities, briefly stated, are to:

1. monitor the rate of sulphate deposition in precipitation (wet deposition), including accumulations in snow;
2. develop environmental standards, termed "target loadings", to protect vulnerable ecosystems;
3. develop mathematical models to describe the phenomenon of transport and deposition of airborne pollutants in the medium (200 km to 500 km) range;
4. measure the deposition rate of sulphate ion in areas not directly under the influence of airborne emissions, and examine the role of dust in precipitation chemistry;
5. measure dry deposition of sulphate, since dry deposition may be a significant portion of total deposition in some locations. Total deposition is the sum of dry and wet deposition, thus both these forms must be measured;
6. monitor the quality of surface waters and the terrestrial environment to identify long-term trends, and to identify areas of greatest sensitivity to acid deposition;
7. document environmental impacts of acid deposition in areas where deposition rates are high, or where sensitivity is high, or both; and
8. review the technology to control emissions and assess the applicability of new technology for use in Western and Northern Canada.

A full statement of these priorities is contained in Section 13 of this report.

The research and monitoring activity reported herein, documents progress in Western and Northern Canada toward a strategy for sound management of acid deposition. The expanded table of contents provides a quick overview of the diverse subject areas contained in the report, and there is a glossary of acronyms and abbreviations for the convenience of our readers.

2. BRITISH COLUMBIA

2.1 EMISSIONS AND CONTROL TECHNOLOGY

Joint work involving the Province is underway. See Section 8.

2.2 AIR QUALITY AND DEPOSITION

Precipitation Chemistry Stations

The province continued to monitor weekly precipitation with automatic samplers at Cranbrook, Kamloops, Kitimat, Smithers, Victoria, Spectacle Lake, Nanoose, Squamish, and Pender Island. A new station in the Greater Vancouver Regional District (Seymour Dam) was added. The province assumed responsibility for federal monitoring stations located at Kelowna, Port Hardy, and Vancouver. At the same time, four provincial stations were discontinued: Dawson Creek, Agassiz, Terrace, and West Sechelt.

Monitoring stations provide weekly data on the rate of sulphate deposition, an index of the acidity of the precipitation. The values for 1985 are: Squamish 16.4, Agassiz 10.4, Victoria 8.4, Sechelt 7.1, Nanoose 6.2, Pender Island 4.4, and Spectacle Lake 3.5 (estimated). The sulphate deposition rates quoted above are expressed in terms of kilograms of sulphate ion per hectare per year, and have been corrected for the presence of sea salt. This correction compensates for airborne sulphate from the ocean that has already been neutralized and does not contribute to the acidity of precipitation.

Rates of sulphate deposition at Cranbrook, Kamloops, Kitimat, and Smithers, are not available for the 1986 Annual Report.

Report: The annual acid precipitation monitoring reports for 1984, 1985, and 1986 are available from the Waste Management Branch, Ministry of Environment and Parks, British Columbia.

Analysis of Transboundary Impacts

The Province examined the possible correlation between the quality of rainfall in Vancouver, British Columbia, and emissions from a copper smelter 200 km to the south. This investigation was based on back trajectories of air movements during October 1984 and October 1985, analysis of rainwater chemistry based on weekly samples, meteorological parameters, and the rate of emission of sulphur dioxide. Emissions from the smelter ceased during the study period. Rain chemistry data reflect this change: the concentration of hydrogen ion (H^+), and sulphate ion ($SO_2^=$) decreased slightly after emissions ceased.

Report: A report is available from the Waste Management Branch, Ministry of Environment and Parks.

Regional Sources of Rainwater Ions in the Lower Mainland

In 1985, principal source regions contributing to the chemical properties of rainwater were identified in the lower mainland of British Columbia, in 1985. Principal factor analysis spanned three major sources of ions in rainwater: sea salt, fuel combustion in the urban areas, and the use of fertilizer and manure in agricultural areas. Canonical discriminant analysis classified data from seven stations into four groups. These four groups are: 1. Victoria; 2. Nanoose; 3. Agassiz; and 4. the remaining stations: Pender Island, Sechelt, Squamish, and Spectacle Lake.

Report: A working report will be available from the Waste Management Branch, Ministry of Environment and Parks, British Columbia.

Photochemical Dispersion Models

The development and validation of photochemical dispersion models for the lower Fraser Valley has been underway since 1985. These models are being used to design and test strategies for the control of photochemical oxidants and related pollutants in the lower Fraser Valley.

This project is multi-faceted and includes the following activities: 1. enhancement of wind networks, and air quality networks; 2. monitoring of the depth of the mixed layer; 3. modelling of a three dimensional wind field; and 4. estimation of the rate of emission of volatile organic compounds. These estimates relate to emissions from point sources, area sources (diffuse sources of waste gases such as home heating), mobile sources (autos and trucks), and from the marketing of motor fuel.

Report: Reports will be available when the various phases of the project are completed. Further information is available from the Ministry of Environment and Parks, Victoria, British Columbia.

Monitoring and Quality Control

The British Columbia Ministry of Environment and Parks continued to participate in LRTAP Inter-laboratory Comparison studies for precipitation and surface waters, and continued to represent Western Canada on the Quality Assurance Sub-group of the Research and Monitoring Co-ordinating Committee (RMCC).

2.3 SURFACE WATERS

Lake Trend Monitoring

To determine whether acidic inputs are causing a significant trend in the deterioration of water quality at sensitive lakes, six lakes on Vancouver Island, Saltspring Island, and in the Lower Mainland are monitored monthly. Analysis of the water samples includes pH, alkalinity, acidity, general ions, and metals. Phytoplankton and zooplankton are collected monthly from May through October. The planktonic organisms are identified, and estimates of algal biomass are made on the basis of the amount of chlorophyll-*a* in the samples. Maps of the distribution of aquatic plants (aquatic macrophytes) are made on the basis of surveys taken every five years. During these surveys, samples of the lake sediments are collected. The program began in 1984, and data are to be analyzed in 1989.

Report: Data are available from the Water Management Branch, Ministry of Environment and Parks.

Background Lake Monitoring

A sampling program to determine the sensitivity of lakes around the province continued. However, the scope of this program is now decreasing.

Report: A report on lake sensitivity is available from the Water Management Branch, Ministry of Environment and Parks.

Water Quality Criteria

Water quality criteria for aluminum and pH are being developed. These criteria are designed to protect a variety of uses, but place greatest emphasis on valued attributes of the British Columbia environment.

Report: Reports will be available in the future from the Water Management Branch, Ministry of Environment and Parks.

Lake Sensitivity Mapping

Lake sensitivity maps for British Columbia have been prepared.

Report: Maps are available from the Water Management Branch, Ministry of Environment and Parks.

2.4 SOILS AND GEOLOGY

Soil and Geology Sensitivity Mapping for British Columbia

Maps of British Columbia, depicting soil and geology sensitivity to acid precipitation, have been in preparation for several years. Mapping methods and sensitivity rating criteria used are based on those outlined by the Coordinating Committee on Soil and Geology Sensitivity mapping. Border matching, and reviews of data and ratings have now been completed, and maps are being drafted in preparation for printing. A report describing methods, data sources, and observations on the sensitivity ratings will accompany the maps. A source map showing delineations and describing soil and geology characteristics significant to interpreting sensitivity will be included.

Report: Further information is available from the Ministry of Environment and Parks, Waste Management Branch, Victoria, British Columbia.

2.5 VEGETATION

Preliminary assessment of economic impacts of ozone (O_3) on agricultural crops in the Fraser Valley was conducted.

Report: Further information is available from the Ministry of Environment and Parks.

2.6 HEALTH

Heavy Metals in Deer

The Wildlife Branch measured the concentration of cadmium and other metals in the livers of ten deer. The samples of liver came from deer taken during the 1986 hunting season in the Skagit Valley, Pemberton, and Texada Island. Cadmium concentrations in the samples were 2 ($\pm$ 1) micrograms, or less, per gram of dried tissue. These concentrations are believed to represent background levels, and are lower than the concentrations found in deer in Ontario and Qubec. In jurisdictions where cadmium concentrations in wildlife are elevated, pathways of intoxication are being studied. The phenomenon may be related to acid deposition and the leaching of heavy metals from soils. See Section 5.6: Cadmium in Moose.

Report: No report is planned. However, further information is available from the Wildlife Branch, Ministry of Environment and Parks.

3. ALBERTA

3.1 EMISSIONS AND CONTROL TECHNOLOGY

Use of Manganese Chloride for Cumulative SO_2 Monitoring

This project, scheduled to begin in 1987, will attempt to find a more accurate method of measuring sulphur dioxide (SO_2) concentrations in the vicinity of sour gas processing plants. Glass tubes containing manganese chloride ($MnCl_2$) solution, equipped with a SO_2 permeation membrane, will be exposed to the ambient air for a period of three to four weeks. The absorption efficiency and effects of various environmental factors such as temperature and humidity will be studied. If a more accurate SO_2 monitoring method is found, the existing lead dioxide (PbO_2) candle exposure method will be replaced.

Report: The results of this program will be available from the Chemistry Wing of the Alberta Environmental Centre, Vegreville.

Sources and Emissions Inventories

Three types of emissions inventories are prepared by the Air Quality Branch of the Pollution Control Division: provincial sulphur emissions, provincial nitrogen oxides emissions, and urban (Edmonton and Calgary) emissions. The sulphur emissions inventory is updated every two years. Annual sulphur emissions (sulphur dioxide expressed as sulphur) for individual plants contributing to the observed (actual) and licensed emissions of each industrial grouping are presented on a year-to-year basis along with trends in both observed and licensed sulphur emissions total. The nitrogen oxides emissions inventory is also updated every two years (offset by one year from the sulphur emissions inventory). Major industrial, transportation, and combustion sources are included. The urban sources and emissions inventory is scheduled to be updated every five years. Quantities of carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2), total hydrocarbons (THC), and particulates from 12 different sources are included.

Report: The reports listed below will be available from the Air Quality Control Branch, Pollution Control Division, Alberta Environment:

Industrial Sulphur Emissions for Alberta 1981-1985 (in preparation).

Nitrogen Oxides Emissions for Alberta 1981-1985 (in preparation).

3.2 AIR QUALITY AND DEPOSITION

Collection of Snow Samples for the Winter Pollution Deposition Study

Accumulated snowpack was sampled and chemically analyzed to document the deposition patterns and spatial variability of snowpack loadings resulting from the emission of pollutants from industrial sources. These snowpack samples were collected at 60 sites in the tar sands area in accordance with Alberta Environment's quality assurance standards. Site characteristics were documented and evaluated to establish representativeness within the network.

Report: A final report will be available in 1987 from the Research Management Division, Alberta Environment.

Determination of Organic Anions in Precipitation

A project has been initiated to develop an ion chromatographic method for measuring organic anions in precipitation. Various columns and eluents will be tested in the analysis. Once the testing is complete and the appropriate procedure has been developed, the ion chromatographic method will be used for the analysis of organic anions and investigation of ion imbalance in precipitation samples.

Report: Results will be available from the Chemistry Wing of the Alberta Environmental Centre, Vegreville.

Effect of Urban Air Quality on Visibility — Phase I

A comprehensive research plan has been developed to: (1) analyze, spatially and temporally, the chemical and physical properties of urban aerosols, (2) determine the relationship between particle mass loading and urban visibility, and (3) assess the effects of aerosols on solar radiation in an urban environment. Monitoring techniques have been developed to quantify levels of individual gaseous pollutants and to produce vertical profiles of aerosol concentrations. Irradiance instruments have been tested to derive a method of determining optical depth and aerosol loadings. A Mie scattering numerical model has been developed and tested to calculate extinction coefficients of light due to scattering and absorption from aerosols.

Report: The final report will be available from the Research Management Division of Alberta Environment.

Precipitation Monitoring Stations

During the period 1978-1984, eleven precipitation monitoring stations operated in Alberta. Precipitation samples were collected and analyzed on a monthly basis. The data were examined for chemical composition, spatial distribution, seasonal variation, temporal trend, acidity and wet sulphate deposition. Alberta precipitation has an average pH of 5.5 relative units. Calcium, sulphate, and ammonium ions are the most common chemical species in precipitation. Higher ion concentrations occur in southern Alberta. Higher volumes of precipitation in the summer months result in lower ion concentrations. No temporal trend is apparent. The average wet sulphate deposition in Alberta is 8.9 kilograms per hectare per year (9.2 millimole/m^2/year). In Alberta, unlike eastern Canada, wet sulphate deposition is not a direct measure of acid deposition because of the significant amount of dry deposition (see Dry Deposition of Acid Forming Emissions in Alberta, below).

Report: A published paper, Acid-forming Emissions in Alberta, is available from the Research Management Division, Alberta Department of Environment, Edmonton, Alberta. Other information is also available from this source.

Dry Deposition of Acid Forming Emissions in Alberta

The total deposition of acid-forming emissions is dependent on two components—wet deposition and dry deposition. In Alberta, dry deposition is considered to be as important as wet deposition close to the sources; the amount of dry deposition relative to the total deposition is not known for Western Canada. There is no routine method suitable for direct measurement of dry deposition rates over an extended network.

The objectives of this dry deposition project are to:

1. evaluate alternate active and passive monitoring techniques for measuring the dry deposition of sulphur and nitrogen oxides;

2. evaluate methods for determining deposition fluxes from atmospheric concentration data and supporting meteorological and biophysical data; and

3. recommend appropriate monitoring or measurement methodologies to routinely measure dry deposition.

Report: A report will be available from the Research Management Division of Alberta Environment.

Application of MESOPUFF II Transport/Deposition Model in the Oil Sands Region

The government of Alberta is assessing the suitability and applicability of the Lagrangian mesoscale deposition model, MESOPUFF II, to determine the concentration and deposition of atmospheric pollutants in northern Alberta and Saskatchewan. The model will be evaluated using representative data sets from northern Alberta and Saskatchewan for selected time periods.

Report: Results will be published by the Research Management Division of Alberta Environment.

The Athabasca Oil Sands Aerometric Monitoring Programme

The province has developed an aerometric monitoring programme for the Athabasca Oil Sands area. Its purpose is to support studies of the environmental impact of airborne pollutants generated by extraction and processing of oil in the area. The time scale of the impact study includes medium term (up to twenty-five years), and long term (greater than twenty- five years). Receptors being monitored for impacts of airborne pollutants include vegetation, soils, and aquatic systems. Airborne pollutants to be monitored include: (1) gases (sulphur dioxide, hydrogen sulphide, and ozone), (2) particulates (sulphate, nitrate, and ammonium), and (3) approximately 20 trace metals. Areas of high, medium, and low rates of impingement will be identified by modelling, and verified with onsite air quality measurements.

Phase I of the project involves the design of the aerometric monitoring program, including: detailed specifications for the design and operation of the aeromonitoring equipment; sampling design; and protocols for quality control and quality assurance of the data. Design criteria developed in Phase I are based on the best available knowledge in the literature, and from consultations with the principal researchers in the field, especially those with expertise in the study of environmental impacts. Phase II involves the implementation of the monitoring program, and the collection, analysis and reporting of the data.

Report: Results will be available from the Research Management Division of Alberta Environment.

Air Quality Data Acquisition in the Oil Sands Area of Northeastern Alberta

An air quality monitoring station was established in the oil sands area near Fort McMurray to monitor the ambient concentrations of acid-forming gases, ozone

and meteorological variables. Monitoring data will be used: (1) in a numerical model to interface air quality with plant response measurements, (2) for the purposes of validating a model which estimates the frequency distribution of ground level concentrations of sulphur dioxide, and (3) to measure the quality of ambient air.

Reports: Annual reports for the years 1983 to 1986 are available from the Research Management Division of Alberta Environment.

Diffusion and Deposition Modelling for Point Source Emissions

A set of models is maintained to estimate concentrations and deposition downwind of point sources. The level of input data determines the selection of the specific model to be used. New models are added as they become available, and the older ones are upgraded as required. Existing and proposed point sources, and complexes of point sources, are evaluated for regulatory purposes. Occasionally, guide models are promulgated for general use.

Reports: The reports listed below will be available from the Air Quality Control Branch, Pollution Control Division, Alberta Environment:

A guide for estimating sulphur deposition resulting from point source emissions (SULDEP2)
STACKS2 User's Guide (in preparation)
STACKS2 User's Guide, Vol. II IBM-PC Version (in preparation)
PLUMES3 User's Guide (in preparation)
PLUMES3 User's Guide, Vol. II IBM-PC version (in preparation)

Precipitation Quality Monitoring Network

The chemical composition of precipitation is monitored at several permanent sites in Alberta. The objective of the project is to detect significant changes resulting from industrialization within the province and to provide an historical database.

Report: Data reports are produced annually, and a five-year summary is in preparation. These reports are available from the Air Quality Control Branch, Pollution Control Division, Alberta Environment.

Exposure Stations

The Exposure Station Program consists of 260 total sulphation stations, and 171 hydrogen sulphide static exposure stations. These monitors are located primarily in and around urban centres and industrial areas of the province and are used to identify trends. Chemical analysis is done by the Alberta Environmental Centre (Vegreville), and the results are expressed in equivalent milligrams of SO_3 per 100 square centimetres per day.

Report: Data summaries are available from the Air Quality Control Branch, Pollution Control Division, Alberta Environment.

3.3 SURFACE WATERS

River Monitoring Network

The objective of the project, which began in 1977, is to establish long-term databases of water quality at selected locations on major Alberta rivers to allow analyses of long-term trends. Nine stations are monitored on a monthly basis.

Report: Data are available from Water Quality Control Branch, Pollution Control Division, of Alberta Environment.

Present and Potential Effects of Man's Activities on Waters Associated with Peatlands in Alberta

The primary objective of this project is to assess the feasibility of using Alberta peatlands for agricultural purposes. This involves four intermediate steps as follows: (1) describe the current state of knowledge with regard to peatlands in Alberta, (2) describe the kinds of activities which may have an impact on these waters, (3) analyze this potential impact and (4) examine the deficiencies in information and knowledge with respect to Alberta peatlands.

Report: A preliminary draft is in preparation and will be available from the Research Management Division of Alberta Environment.

3.4 SOILS AND GEOLOGY

Soil Sensitivity Mapping

The objective of the project, which began in 1984, was to prepare maps of Alberta at 1:2,000,000 scale depicting the distribution of the relative sensitivity of soils to acid deposition, and potential of soils to neutralize acid deposition. Approximately 200 unique map units have been identified, described, and interpreted.

Report: A soils map of the province at 1:2,000,000 scale that synthesizes the best available soil data for the province is now available.

It is expected that the soils map and report will be available in 1987 from the Alberta Research Council.

Sensitivity of Soils in Alberta to Acid Additions

In an attempt to map soils on the basis of their sensitivity to acidification, the project investigated: (1) whether soil survey information could be used to assess relative sensitivity of soils, and (2) which soil characteristics are most useful in predicting buffering capacities. It was concluded that present mapping based on soil series does allow a wide variety of soil chemical properties to be distinguished. Current emphasis on cation exchange capacity for soil sensitivity is supported by this project.

Report: A final report will be available in 1987 from the Earth Sciences Division of Alberta Environment.

Seasonal Fluctuations in Soil pH

The project was initiated in 1983 to document the relative importance of seasonal variations in soil chemical properties as an aid to identifying long-term acidification. A statistical model has been developed that considers the implications of spatial and temporal variation for the process of monitoring for soil acidification.

Report: A detailed report documenting the spatial and temporal variability in soil pH and other soil properties at seven sites over a two-year period will be available in 1987 from the Earth Sciences Division of Alberta Environment.

Long-Term Measurement of the Acidification of Non-Cultivated Soils in Alberta

Eight monitoring sites have been established to measure the acidification of soils over a long period of time in areas where deposition of industrial acid precursors is expected to occur. The monitoring sites are intended to measure the worst situations, hence they will act as soil acidification early warning sites. Two sites have been sampled each autumn since 1981. All sites will be resampled once every four years.

Report: A brief synthesis of procedures is available from the Earth Sciences Division of Alberta Environment.

3.5 VEGETATION

Impact of the Lodgepole Blowout Gases on a Forest Ecosystem

The province has implemented a monitoring project to determine the environmental impact of the Lodgepole blowout gases on a forest ecosystem. Biologically similar plots were established upwind and downwind from a well for the purposes of monitoring the effects of the Lodgepole blowout on the forest ecosystem within a 10 km radius. The data collected included tree biomass, stand condition, understory species composition, soil horizon characteristics, tree volume, and tree growth. Data pertaining to the occurrence of insects and disease were also collected. Preliminary results show that hydrocarbons emitted from the well discharge have caused considerable damage. Sulphur compounds appear to have had a negligible effect.

Report: Initial results are available from the Alberta Forest Service.

Athabasca Oil Sands — Research Plan

Staff of Alberta Environment developed a research plan for a five-year study of acid deposition, and its potential effects, in the boreal forest region near the Fort McMurray oil sands plants. The main goals of the research are: 1. measure indices of tree health in an air pollution gradient to determine whether biological monitors can be used to predict the potential effects of acid deposition close to the sources of acid pollutants, and 2. collect concurrent data on air quality, meteorology, and vegetation response over an air pollution gradient to determine whether cause/effect relationships can be developed. The research plan is based on a year-long review of research already conducted in the Athabasca oil sands region, and of information generated by the Western and Northern Canada LRTAP Technical Committee, jointly funded research programmes of industry and government, and other research programmes. The proposed research plan underwent a critical evaluation at a two-day workshop. Revisions to the plan based on this workshop are being made, and preliminary work on the research program is expected to start in 1987.

Report: Further information is available from G.A. Singleton, Research Management Division, Alberta Environment.

3.6 HEALTH

Health Effects of Sulphur Gases

Research is being conducted by the Alberta Environmental Centre for three government departments to determine the effects of toxic or potentially toxic gases, vapours, particulates, and aerosols on animals, and by extrapolation, on man. A series of 15 studies on the pathological, biochemical, and cytological effects of a single acute exposure of rats to various concentrations of hydrogen sulphide is nearing completion. Studies on the effects of repeated exposure to hydrogen sulphide have been initiated. *In vitro* studies of sulphide toxicity are continuing.

Report: Reports and publications are available from the Animal Sciences Wing of the Alberta Environmental Centre, Vegreville.

4. SASKATCHEWAN

4.1 EMISSIONS AND CONTROL TECHNOLOGY

Saskatchewan Air Emissions Inventory of Sulphur Dioxide and Nitrogen Oxides

The inventory of sulphur dioxide and nitrogen oxides emissions is being updated for the year 1985. The inventory will be prepared according to the methods outlined in the emissions inventory methods manual developed by the Western Canada LRTAP Inventory Technical Working Group.

Report: A final report will be available in 1987 from the Air Quality Branch, Saskatchewan Environment and Public Safety.

4.2 AIR QUALITY AND DEPOSITION

Poplar River Thermal Power Plant Ambient Air Monitoring Program

Saskatchewan Environment and Public Safety monitors sulphur dioxide and suspended particulates at one location, Coronach. Few detectable concentrations have been recorded at this site. The highest hourly concentration recorded in 1986 was 0.024 parts per million (ppm), well below the provincial standard. The 24-hour average suspended particulates concentrations were within the provincial standards.

Report: Data summaries are available from the Air Quality Branch, Saskatchewan Environment and Public Safety.

Snowpack Chemistry in Northern Saskatchewan

To supplement the snowpack chemistry studies conducted in Northern Saskatchewan, Saskatchewan Environment and Public Safety has established a long-term snowpack chemistry monitoring program. The program involves the annual collection of snow samples at seven sites in northern Saskatchewan. The samples are analyzed for pH, sulphate, nitrate, chloride, ammonium, alkalinity, and metal ions. The next set of samples will be collected in February or March 1987.

Report: Data summaries are available from the Air Quality Branch, Saskatchewan Environment and Public Safety.

Chemistry of Summer Precipitation in Northern Saskatchewan

Rainfall is collected, on an event basis, at seven sites in northern Saskatchewan. Chemical analyses for sulphate, nitrate, chloride, ammonium, potassium, calcium, sodium, magnesium, pH, alkalinity, and metal ions provide data for evaluation of deposition rates.

Report: Data summaries are available through the Air Quality Branch, Saskatchewan Environment and Public Safety.

4.3 SURFACE WATERS

Surface Water Sampling in Northern Saskatchewan

Approximately 60 surface water stations in northern Saskatchewan are monitored. Most of the samples are collected by industry at the request of Saskatchewan Environment and Public Safety.

Report: Data summaries are available from the Mines Pollution Control Branch, Saskatchewan Environment and Public Safety.

Lake Water Chemistry for Small Lakes in Northern Saskatchewan

A long-term program to monitor lake-water chemistry was initiated by Saskatchewan Environment and Public Safety in 1984. Water samples are collected each year at 22 sites uniformly distributed throughout northern Saskatchewan. Analysis of the samples includes: pH, sulphate, nitrate, calcium, magnesium, alkalinity, and aluminum, and may also include associated ions, metals, nutrients, and solids measurements.

The data indicate that these small lakes contain low concentrations of major ions, however, pH levels remain above 6.0 relative units.

Report: Data summaries are available from the Air Quality Branch, Saskatchewan Environment and Public Safety.

Lake Sensitivity Mapping

Lake sensitivity maps have been prepared for the province: one based upon alkalinity data, one based upon calcium data, and one in which sensitivity classi-

fications for both calcium and alkalinity maps are combined. The maps have been modified at the borders to match up with maps being prepared by Alberta and Manitoba. All maps are based on criteria outlined by the Co-ordinating Committee on Surface Waters.

Report: Copies of these maps are available from the Air Quality Branch, Saskatchewan Environment and Public Safety.

4.4 SOILS AND GEOLOGY

Soils and Geology Sensitivity Mapping

Maps of Saskatchewan depicting soils and geology sensitivity to acid precipitation have been prepared by the Saskatchewan Institute of Pedology. The maps have been modified at the borders to match up with the maps being prepared by Manitoba and Alberta. The maps are based on the criteria outlined by the Co-ordinating Committee on Soils and Geology Sensitivity Mapping.

The initial mapping exercise identified a large triangular area in northwestern Saskatchewan where no data existed. In 1986 the Saskatchewan Institute of Pedology collected the data necessary to fill the data gap. The soils and geology sensitivity maps are being updated to include these data. This has delayed the availability of the sensitivity maps.

Report: The maps and a report will be available in 1987 from the Air Quality Branch, Saskatchewan Environment and Public Safety, and the Saskatchewan Institute of Pedology, University of Saskatchewan.

4.5 VEGETATION

An Evaluation of the Sensitivity of Saskatchewan Forest Vegetation and Field Crops to Acidic Precipitation

The response of five Saskatchewan forest and crop species to simulated acid rain was studied under controlled conditions in a growth room. Jack pine, aspen, alfalfa, wheat and canola were subjected to weekly applications of simulated rain with pH 5.6, 4.6, 3.6, and 2.6 relative units for up to 22 weeks. Variables evaluated were: yield, underground bio-mass, leaf or needle chlorophyll content, visible injury, and foliar nutrient content. Soil variables included in the analysis were: water soluble ions, exchangeable cations, and available nutrients. Assimilated acid rain with pH 3.6 or higher had minimal effects on the forest and crop species investigated. Since plants sensitive to acid rain are affected at a pH of 4.0 or higher, none of the species investigated could be classified as sensitive.

Report: A report is available from Saskatchewan Environment and Public Safety, and the Saskatchewan Research Council.

4.6 HEALTH

Long-Range Transport of Air Pollutants — Health Effects

A joint epidemiological study between Health and Welfare Canada, and Saskatchewan Environment and Public Safety, began in 1985 on school-aged children to assess the potential risk to human health from the long-range transport of air pollutants. Details of this study are outlined in Section 8.6.

5. MANITOBA

5.1 EMISSIONS AND CONTROL TECHNOLOGY

Emission Inventories

No specific studies are underway with respect to emissions and control technology. However, emission inventories for nitrogen dioxide and sulphur dioxide are being maintained by the province.

Report:3. A report of nitrogen dioxide and sulphur dioxide emissions for 1985 has been completed. Data summaries for succeeding years are also available from Manitoba Environment and Workplace Safety and Health.

5.2 AIR QUALITY AND DEPOSITION

Air Quality Monitoring in Northern Manitoba

Atmospheric sulphur dioxide is measured on a continuous basis downwind from the two major non-ferrous smelters at Flin Flon and Thompson. The network consists of two stations within the Flin Flon area and one in Thompson. Total reduced sulphur compounds are measured at one site near the MANFOR kraft pulp and paper mill at The Pas. Levels that exceed the provincial air quality objectives/guidelines are observed on occasion, primarily because of meteorological conditions and not as a result of mine operations.

Report: Data summaries and reports are available from Manitoba Environment and Workplace Safety and Health.

Precipitation Monitoring

Precipitation is sampled on a daily event basis at Norway House, Island Lake, Gillam, Brochet, Winnipeg, and Pointe du Bois. The following variables are analyzed: pH, conductance, acidity, sulphate, nitrate, chloride, calcium, ammonium, magnesium, sodium, and potassium. Annual volume-weighted mean pH levels are about 5 pH units in remote areas; levels at Winnipeg are higher. Wet sulphate deposition values are at levels near background and range from 4 to 6 kilograms per hectare per year.

Report: Data summaries and reports are available from Manitoba Environment and Workplace Safety and Health.

Snowpack Survey

A winter snowpack survey is being conducted within the boreal forest ecosystem surrounding the smelters in Flin Flon and Thompson. Seven sampling sites are located around Flin Flon and twelve near Thompson. At each site replicate samples are taken and analyzed for pH, sulphate, zinc, lead, copper, nickel, iron, cadmium, and arsenic.

The snowpack survey includes 18 stations throughout the province. Samples are analyzed for pH, conductance, acidity, sulphate, nitrate, chloride, calcium, ammonium, magnesium, sodium, and potassium.

A report is available for the sampling carried out near Flin Flon during the period 1981-83. Analysis of the data from the Flin Flon area for the period of 1983 indicates that zinc is the major metal found in snow; however, copper, iron, and lead are also found. The amounts of these metals all decrease in the snow with the distance from the smelter. Small amounts of cadmium are also found but there is not a clear relationship with distance from the smelter. Sulphate deposition is highly variable, but there is a general decreasing trend away from the smelter. The pH of the snow is variable and, in most cases, is greater than 5.6 pH units. Deposition of zinc, copper, iron, lead, and cadmium decreased markedly from 1982 to 1983. The decrease is attributed to the installation of a new electrostatic precipitator on the zinc smelting process at the Flin Flon Smelter in November 1982.

Cursory examination of the data from the Thompson area indicates that nickel and copper are deposited as far away as 12 km from the smelter. Snow pH does not seem to be affected by the smelter emissions.

Cursory examination of the data collected throughout the province indicates that the sulphate deposition is generally less than 1 kilogram per hectare per year. Depressed pH values (below 5.6 pH units) have been recorded at most sites, but not consistently. The lowest pH reading was recorded at Island Lake (pH 4.5).

Report: Data summaries or reports, or both, are available through Manitoba Environment and Workplace Safety and Health.

5.3 SURFACE WATERS

Surface Water Sampling

Approximately 3400 sites located within National Topographic Series map sections 53E, 53F, 53K, 53L,

and 53M of northern Manitoba were sampled as part of a Geochemical Reconnaissance Program operated jointly by Manitoba Geological Services Branch and the federal government. Analyses of calcium, magnesium, alkalinity, and pH were carried out by Environment Canada. The data obtained from the surface water quality sampling have been used to prepare aquatic sensitivity maps. In general, acidified water bodies have not been found, except for some bogs and acid mine drainage areas.

Report: Data summaries are available through Manitoba Environment and Workplace Safety and Health.

Aquatic Sensitivity Mapping

Aquatic Sensitivity maps were prepared for inclusion with the overall aquatic sensitivity maps of Western Canada. Aquatic areas sensitive to acid deposition have been found in the northwestern corner of the province and east of Lake Winnipeg.

Report: Data summaries are available through Manitoba Environment and Workplace Safety and Health.

5.4 SOILS AND GEOLOGY

Terrestrial Sensitivity Mapping

Terrestrial sensitivity mapping was completed in co-operation with other jurisdictions of Western Canada. Considering surface soils and bedrock characteristics, areas of high sensitivity to acid deposition were found on the east side of Lake Winnipeg and in the northwest corner of the province. In these areas the potential of soils and bedrock to reduce the acidity of incoming acidic deposition is low, similarly indicating a high sensitivity to acid rain.

Report: Two maps have been produced at a scale of 1:2,000,000. These are:

1. Sensitivity of Soils to Acidic Inputs
2. Potential of Soil and Bedrock to Neutralize the Acid of Incoming Acidic Deposition.

A report including both maps is available through Manitoba Environment and Workplace Safety and Health.

5.5 VEGETATION

Vegetation Surveys Around Northern Smelters: Tree Seedling Studies

Greenhouse studies of tree seedlings grown in heavy-metal contaminated soil from Thompson have been completed. In 1986 this research was expanded to study metal effects from the Flin Flon smelter. The study near Thompson indicated differences in physical development of seedlings between sites over a 24-week growing period in a greenhouse. Toxic levels of metals, especially nickel and copper, apparently are being absorbed by the seedling root tissue. Significant growth inhibition of seedling roots is occurring in soil within a 5 km radius from the smelter. There is concern that metal concentrations in the surface organic layer ("LFH" medium) may be contributing to a decline in the ability of these species to regenerate successfully. The results of this study remain to be field tested.

Report: A report is available from Manitoba Environment and Workplace Safety and Health.

Tree Regeneration Study Near Thompson

Greenhouse studies were followed up at four plots established near Thompson with financial assistance from Inco Limited. These plots are used for onsite studies of plant growth in soils contaminated by the Thompson smelter. Tree seedlings have been transplanted on the study plots, and soil surveys have been completed.

Report: The study is ongoing. Interim results are available from Manitoba Environment and Workplace Safety and Health.

Terrestrial Monitoring

In co-operation with the federal ARNEWS program, three additional sampling sites were added to the existing five sites established in 1985. Presently, four sites are under federal/provincial management and four are under provincial management. Two additional sites are planned for 1987.

Report: Baseline data have been collected, and data summaries will be available from Manitoba Environment and Workplace Safety and Health.

5.6 HEALTH

Mercury in Mink and Otter

Mercury levels in mink and otter in the Rat-Burntwood system have been monitored. The study was completed in 1986. Mercury concentrations in the tissues of mink and otter in the Rat-Burntwood areas were higher than in most areas of southern Manitoba. A small percentage of aquatic furbearers have accumulated near-toxic concentrations of mercury in their tissues. Mercury concentrations in mink have decreased over the past two

years but no conclusion can be reached regarding long-term trends. It is speculated that the mercury originated from water manipulations within the Churchill-Nelson river system and not from the long-range transport of airborne pollutants.

Report: A report is available from Manitoba Environment and Workplace Safety and Health.

Cadmium in Moose

Cadmium levels in moose in areas of high potential sensitivity to acid rain have been monitored during 1985 and 1986. Samples of moose kidney and liver were analysed. Cadmium levels in kidney ranged from 0.9 to 13.0 milligrams per kilogram (wet weight). These concentrations are much lower than those found in Ontario and Sweden. The cadmium in liver ranged from 0.3 to 4.9 milligrams per kilogram (wet weight). Cadmium is found at higher concentrations in older animals. (See also: Section 2.6. Note that the cadmium concentrations referred to in Section 2.6 are for deer, not moose, and are expressed in dry weight, not wet weight. The units of measure "milligrams per kilogram" and "micrograms per gram" are interchangeable. Ed.)

Report: A report is available from Manitoba Environment and Workplace Safety and Health.

6. NORTHWEST TERRITORIES

6.1 EMISSIONS AND CONTROL TECHNOLOGY

No activities were conducted in this area.

6.2 AIR QUALITY AND DEPOSITION

Aerosol Deposition

The Northwest Territories is supporting a three-year study of aerosol deposition in snow cores, lake bottom sediment, and glacial ice in the central arctic. The study is being undertaken by Mr. Dennis Gregor, of the Inland Waters Directorate, Regina, Saskatchewan.

Report: Further information is available from the Inland Waters Directorate, Regina, Saskatchewan.

Precipitation Chemistry

Precipitation chemistry samples were taken at Inuvik and Yellowknife, but analytical results are not yet available. These stations — Inuvik and Yellowknife — will be replaced by a CAPMON station.

Report: Further information is available from the Pollution Control Division, Department of Renewable Resources, Northwest Territories, Yellowknife.

6.3 SURFACE WATERS

Aquatic Sensitivity Mapping

The aquatic sensitivity map was completed by the Inland Waters Directorate in Regina, Saskatchewan.

Report: The report on aquatic sensitivity to accompany the map is in draft stage, but the map is available from the Inland Waters Directorate in Regina, Saskatchewan.

6.4 SOILS AND GEOLOGY

Soils and Geology Sensitivity Mapping

Maps presenting the potential of soils and bedrock in the Northwest Territories to reduce the acidity of precipitation have been prepared. Soil depth, soil texture, bedrock exposure, and bedrock lithology, were used for these interpretations. The maps were based on guidelines prepared by the Task Group on Soils and Geology Sensitivity Mapping. These guidelines ensure compatability with maps prepared by the western provinces and the Yukon Territories.

Report: Further information is available from the Pollution Control Division, Department of Renewable Resources, or from the Lands Directorate, Ottawa, Ontario.

6.5 VEGETATION

No activities in this area.

6.6 HEALTH

Polar Bear Study

The Northwest Territories Wildlife Service and the Canadian Wildlife Service continued to take tissue samples from polar bears to measure the concentrations of polychlorinated biphenyls (PCB) and other organochlorides.

Report: Further information is available from the Wildlife Service, Department of Renewable Resources (Yellowknife) and the Canadian Wildlife Service (Edmonton).

Blood Samples — Native Population

The study of polychlorinated biphenyls (PCB) concentrations in the native people of Broughton Island continued. This study, conducted by the federal departments of Health and Welfare, Indian and Northern Affairs, and Fisheries and Oceans, is based on the analysis of PCB concentrations in breast milk and blood, and in the diet of the people.

Report: Further information is available from Health and Welfare Canada (Ottawa).

7. FEDERAL GOVERNMENT

7.1 EMISSIONS AND CONTROL TECHNOLOGY

Western Canada Sulphur Dioxide and Nitrogen Oxides Atmospheric Emission Inventory Methods Manual (1986 Edition)

The Western Canada Air Emission Inventory Working Group was requested by the Western and Northern Canada LRTAP Technical Committee to prepare a manual containing standard procedures for the compilation of SO_2 and NO_x atmospheric emissions data from point and area sources across Western Canada. The manual is designed to be used by all agencies to ensure uniformity of recording and reporting emissions data. The manual, which was completed in 1986 and contains current methodologies, including emissions factors for the estimation of SO_2 and NO_x emissions.

Report: The manual is available on request from: Western and Northern Region, Environmental Protection, Conservation and Protection, Environment Canada, Edmonton.

1983 Western Canada Sulphur Dioxide and Nitrogen Oxide Atmospheric Emissions Inventory

Industrial point sources and diffuse sources of SO_2 and NO_x emissions are currently being inventoried by provincial agencies across western Canada for the base year 1983. Each of these inventories is prepared using a recently developed manual, then submitted to Environment Canada for regional information and publication through the LRTAP Technical Committee. Information is published both on a "by province" and "sector-wide" basis.

Report: The inventory is expected to be completed in 1987. Information is available from: Western and Northern Region, Environmental Protection, Conservation and Protection, Environment Canada, Edmonton.

A Review of Flaring in the Sour Gas Industry with Particular Reference to the Emission of Pollutants

The objectives of the project were to: prepare a review of the emission of pollutants, including organic chemical compounds, from the flare stacks of natural gas processing plants during periods of upset operating conditions, and; devise a research program for the sampling and analysis of flare gases. The report, which is near completion, contains a detailed literature review of sour gas industry flaring, a review of the wide variation in flare stack operating conditions, and a review of the many problems associated with emission testing. A detailed three-year study program is proposed in the report. In addition, a contract has been let to a consultant to assess current flaring technology worldwide. A government-industry consultative committee has been formed to recommend research on flaring in Alberta.

Report: Information is available from: Western and Northern Region, Environmental Protection, Conservation and Protection, Environment Canada, Edmonton.

Inventory of Point Sources and Emissions in British Columbia

A contract study was initiated to complete an inventory of emissions for the LRTAP precursor pollutants for 1985. This study will provide an updated data base for emissions consistent with emissions inventories being developed for the other western provinces.

Report: Information is available from: Pacific and Yukon Region, Environmental Protection, Conservation and Protection, Environment Canada, West Vancouver.

Volatile Organic Compound Emissions from Gasoline Marketing Operations

As part of the British Columbia Lower Mainland Oxidants Study to develop a comprehensive inventory of emissions of volatile organic compounds, a contract study was initiated to investigate the emissions from gasoline marketing operations. Emissions will be determined for all of the fuel handling stages from the refinery gate to the vehicle refuelling stations. The gasoline vapour will be analyzed and mass emission rates will be determined for each of the organic compounds. All of the emission sources will be located on a grid map, five kilometres square, to facilitate photochemical oxidant modelling.

Report: Information is available from: Pacific and Yukon Region, Environmental Protection, Conservation and Protection, Environment Canada, West Vancouver.

7.2 AIR QUALITY AND DEPOSITION

Oceanic Background Sources of Chemicals Contributing to Acidity in Marine Precipitation

A laboratory for acid rain study was established jointly by the Atmospheric Environment Service and Fisheries and Oceans Canada, at the Institute of Ocean Sciences, Sidney, British Columbia. A METROHM pH system and an ion liquid chromatograph were set up to measure the acidity and major ion compositions respectively for rain samples collected on cruises in the NE Pacific Ocean and the Strait of Georgia. Rain samples were collected at open-ocean locations, or in coastal inlets facing the onshore winds from the open Pacific. These samples were found to have relatively high pH (5.5 relative units), and high concentrations of chloride (Cl^-) and sulphate ($SO_4^=$). Concentrations of nitrate (NO_3^-) were low. In remote inshore Jervis Inlet, the pH was 5.0 relative units, and in the Strait of Georgia off the lower mainland of British Columbia, the pH was 4.4. High nitrate values in the 1.5 to 2.0 parts per million (ppm) range were found in marine air samples near the lower mainland. The presence of these nitrates indicates the possible influence of urban and industrial inputs. The laboratory also participated in the LRTAP interlaboratory calibration exercise.

Report: Information is available from the Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia, attention C.S. Wong.

Hydrometeorology of the CANSAP Sampler

To determine the evaporative loss and under-catch of the CANSAP sampler, CANSAP and CAPMON samplers have been installed at the Regina Airport. Samples are weighed daily, and a comparison of the sample weights is made.

Report: Further information is available from: Central Region, Atmospheric Environment Service, Regina. A final report on the project is expected to be completed in 1987.

Canadian Network for Sampling Precipitation (CANSAP)

Stations in this network have samplers that open only during precipitation events. Samples are removed daily and analyzed on a monthly basis for pH, conductivity, sulphate, nitrate, chloride, ammonium, potassium, sodium, magnesium, and calcium. In 1986 the network included the following stations in Western and Northern Canada, all of which operated for part of the year, with the exception of Whitehorse:

Alberta
- Fort McMurray
- Coronation
- Edson
- Lethbridge
- Rocky Mountain House

British Columbia
- Fort St. John
- Fort Nelson
- Vancouver
- Terrace
- Prince George
- Kelowna
- Port Hardy
- Revelstoke

Northwest Territories
- Inuvik

Yukon
- Whitehorse

The CANSAP network is gradually being replaced by CAPMON (see below).

Report: Data from the network are available from the Atmospheric Environment Service.

Canadian Air and Precipitation Monitoring Network (CAPMON)

CAPMON is a regional scale air and precipitation monitoring network with siting criteria and sampling protocols much more stringent than that of the CANSAP network. Daily samples are analyzed for the same ions as for CANSAP (see above). The western Canada portion of the network in 1986 consisted of the following:

Manitoba
- McCreary
- Island Lake

Saskatchewan
- Cree Lake

In addition, a new station has been established at Esther, Alberta representing an expansion of the national program into Alberta. The station will be operated under contract with sample analyses and data falling under the national quality control and assurance criteria. A search for a suitable CAPMON site in southwestern British Columbia was initiated.

Report: Data summaries are published routinely and are available from the Atmospheric Environment Service.

British Columbia Transboundary Precipitation Chemistry

A precipitation-event sampling network on a line parallel to the United States-Canada Boundary in Southwestern British Columbia, which was first established in 1983, continued operation in 1986. Concentrations of major ions (sulphate, nitrate, ammonia, sodium, chloride) have been monitored throughout the period of operation, as have trace metals Arsenic (As), Lead (Pb), Cadmium (Cd), and Vanadium (Va) for the period October 1984 to February 1986. Data are being analyzed, in part, to determine the effect of the closure of a major SO_2 emitter (the ASARCO smelter in Tacoma, Washington). A preliminary analysis indicates a marked decrease in the concentration of arsenic in precipitation following the closure of the smelter in March 1985. Concentrations of other ions (sulphate, nitrate) also decreased but the association with the closure of the smelter is not well established.

Report: Various reports and data are available from the Pacific Region, Atmospheric Environment Service, Vancouver.

West Coast British Columbia Background Sulphate

To determine the background concentrations of sulphate in precipitation along Canada's west coast, the Atmospheric Environment Service let a contract to analyze available precipitation chemistry data from the region. The study, completed in March 1986, indicated background sulphate concentrations of the order of 6-10 microequivalents per litre with a mode of 8 microequivalents per litre.

Report: A limited number of copies of the report, Background Concentrations of Sulphate in Precipitation Along the British Columbia Coast, Report PAES 86-1, are available from Pacific Region, Atmospheric Environment Service, Vancouver.

Western Canada Deposition Modelling

Three statistical Long-Range Transport of Air Pollution models have been implemented on the Atmospheric Environment Service mainframe computer in Downsview, Ontario. Data bases are being constructed under contract for these models. Annual and seasonal sulphur deposition values for Western Canada be will estimated from the models, and model outputs will be compared.

Report: Periodic progress reports will be available from the Western Region, Atmospheric Environment Service, Edmonton, Alberta.

Regional Trajectories

The Atmospheric Environment Service (AES) is evaluating the ability of existing trajectory models to produce regional-scale trajectories based on available data in the regional computer in Edmonton and the mainframe computer in Downsview, Ontario. A comparison of trajectories produced by smaller-scale regional wind models and the AES trajectory model is continuing. Trajectories produced will be verified against analyzed wind fields and aircraft tracking data where available.

Report: Further information is available from the Western Region, Atmospheric Environment Service, Edmonton, Alberta.

7.3 SURFACE WATERS

Field Electronic Data Acquisition

The objectives of the program are to:

1. develop electronic measurement capability;
2. evaluate the potential for reducing water quality monitoring costs through automated data-gathering methods;
3. collect data for the evaluation of the statistical nature of water quality parameters in coastal streams; and
4. determine the effects of rain on stream pH.

A data acquisition station is currently located at the Salmonid Enhancement Program Hatchery in Maple Ridge in the Kanaka Creek drainage, British Columbia. Monitoring of the following variables is being done at 15-minute intervals: pH, conductivity, depth, oxidation reduction potential, dissolved oxygen, water temperature, air temperature, and precipitation. Data are being collected using Microscout and Terra 8 electronic data gathering systems. Some measurements of alkalinity and acidity during rainstorm events are being made.

Report: High Frequency Water Quality Monitoring of a Coastal Stream (*In:* Proceedings of the Workshop on the Statistical Aspects of Water Quality Monitoring).

Rainfall-driven pH depressions in a British Columbia Coastal Stream (*In:* Monitoring, Modelling and Mediating Water Quality).

Further information is available from the Water Quality Branch, Inland Waters and Lands, Pacific and Yukon Region, Conservation and Protection, Environment Canada.

Acidic Deposition Impact Studies — Manitoba

The Freshwater Institute of Fisheries and Oceans Canada conducts research to determine the impact of, and to understand the fundamental mechanisms of, acidification and associated metals in oligotrophic lakes and freshwater organisms. This research is conducted in whole-lakes under the impact of a base metals (zinc, copper, cadmium) smelter (Flin Flon, Manitoba), in the Experimental Lakes Area, and in laboratories of the Institute. Research highlights for the two major projects are as follows:

Experimental Lakes Area (Northwestern Ontario)

In Lake 223, which has been acidified experimentally since 1976, direct toxicity effects of hydrogen and food chain effects on the biota were observed at relatively high pH values (5.5–6.0), and all species of fish stopped reproducing at pH 5.1. Over the past three years, the mean epilimnetic pH has been permitted to rise to 5.5 from 5.1. Lake trout condition has improved markedly and preliminary evidence indicates a resumption of lake trout reproduction.

In Lake 302, a double-basin acidification study has been underway since 1980. The pH of the basin receiving additions of sulphuric acid has been reduced to 5.0 while the basin receiving an equal amount of nitric acid reached a mean pH of approximately 6.0 during 1986. Nitric acid continues to be much less effective as an acidifying agent than does sulphuric acid, because of neutralization by plant uptake and by denitrification.

A whole lake cadmium experiment is planned to begin on Lake 382 in 1987. This will involve both radiotracer and "cold" cadmium additions to delineate both ecological pathways and physiological effects.

A wetland acidification experiment, underway since 1983, continues on the Lake 239 bog. Effects of outflow chemistry are being monitored and the direct effects on flora and insect fauna are under observation. See Report, below.

Ecotoxicology

Laboratory and field studies are underway to understand the fundamental mechanisms of acid/metal toxicity in freshwater organisms, to develop sensitive and meaningful indicators of stress for use in field situations, and to detect and interpret contamination of the fishery by mercury and other heavy metals due to atmospheric emissions from fossil fuel combustion and metal mining and smelting activities. A few of the findings are: (1) fish exposed to acidic pH values in the field exhibited a wide range of stress responses including ionoregulatory failure, ascorbic acid and glycogen depletion, cortisol increases and morphalogical alterations in head, kidney and gill; (2) chemosensory responses and associated behaviors are very sensitive to acid and metal additions; (3) exposure of fish to sublethal concentrations of metals causes acclimation to metal toxicity and increases in concentration of a metal binding protein, metallothionein; and white suckers in waters receiving atmospheric emissions from the base metal smelters in Flin Flon, Manitoba had elevated metallothionein concentrations in the liver, gill, kidney and intestine.

Report: Further information on the Experimental Lakes Area, and on Ecotoxicology is available from the Freshwater Institute, Fisheries and Oceans Canada, Winnipeg.

Monitoring

Pacific Region Baseline Surface Water Chemistry Monitoring

Weekly surface water data collection (pH, alkalinity, conductivity and colour and metals, seasonally) was continued on selected lower order salmon streams in the Pacific Region in 1986. Monitoring was concentrated in the Vancouver and Lower Mainland area where localized depositions may be having impacts on surface water quality. Episodic pH depressions and conditions of consistently low alkalinity have been documented.

Report: Publication of a departmental technical report on the 1985-86 data is anticipated by summer 1987. Further information is available from Fisheries and Oceans Canada, Pacific Region, Vancouver.

Water Chemistry Sampling — Northwest Territories

Water Quality Branch of Western and Northern Region, Inland Waters/Lands, Environment Canada, collects water samples for major ion and metals analysis at a total of 44 sites in the Northwest Territories. Some of these sites are appropriate for LRTAP surface water monitoring.

Report: Further information is available from Inland Waters/Lands, Environment Canada, Yellowknife.

Water Chemistry Sampling — Prairie Provinces

Environment Canada monitors a large number of surface water sites in the Prairie provinces on a monthly basis, or at the time-of-visit. This monitoring is conducted as part of the Water Quality Branch program or as a result of agreements with the provincial governments or agencies.

Report: Further information is available from Inland Waters/ Lands, Environment Canada, Regina.

Aquatic Sensitivity Mapping — Saskatchewan, Manitoba, Northwest Territories

Environment Canada supported the aquatic sensitivity mapping of Saskatchewan, Manitoba, and the Northwest Territories by providing data base development and computerized isotherm mapping of indicator parameters.

Report: The activity is completed. Further information is available from Inland Waters/Lands, Environment Canada, Regina.

Water Quality Study of Elk Island National Park

Inland Waters/Lands, Environment Canada, and Parks Canada, have co-operated on a water quality study of Elk Island National Park. This study attempted, among other things, to assess the relative impact on the Park's aquatic environment of industrial activities nearby. Intensive sampling to detect the deposition of acidic, organic or other related contaminants, has been undertaken. Sampling included lake water, bottom sediments, biota, ground water, and snow.

Report: A report will be issued in 1987. Further information is available from Inland Waters/Lands, Environment Canada, Regina.

7.4 SOILS AND GEOLOGY

Yukon Soils and Geology Sensitivity Mapping

The objective of the project is to produce maps of: (1) the potential of soil and geology to reduce the acidity of incoming acid deposition affecting the aquatic resource, and (2) soil sensitivity to acid deposition affecting vegetation.

Report: In press. Further information is available from the Canadian Forestry Service, Victoria.

7.5 VEGETATION

Acid Rain National Early Warning System (ARNEWS)

The Acid Rain National Early Warning System was established to clearly and accurately detect early signs of acid rain damage to forests before damage becomes obvious. A nation-wide network of permanent plots has been established by the Canadian Forestry Service to detect and monitor changes in forest soil, vegetation, and trees.

The objective of the program is to obtain baseline data on the concentrations of foliar and soil elements, foliar and tree condition (including insect and disease levels), and tree growth. The baseline studies are to be followed up by detection and monitoring of possible changes to the baseline conditions over a planned 20–25 year period.

Fifteen nationally standardized forest plots have been established as part of the ARNEWS program in British Columbia. Detailed soil and foliar chemical analyses are available for nine British Columbia plots.

To obtain a more immediate assessment of the condition of the forest in British Columbia, Forest Insect and Disease Survey (FIDS) undertakes subjective observation of the province-wide permanent sample plots. To date, additional observations have been made on 592 plots.

In the Prairie Provinces, the FIDS unit has established 12 ARNEWS plots: five in Alberta, three in Saskatchewan and four in Manitoba. All plots conform to the nationally standardized reporting format and are scheduled to remain in existence for 20–25 years.

Report: Further information is available from the Canadian Forestry Service, Victoria and Edmonton.

Biomonitoring Studies on Selected ARNEWS Plots

Thirty-four subplots were established in five British Columbia ARNEWS sites. Presence, health and per cent cover of terrestrial mosses, lichens, and liverworts were recorded. Six permanent arboreal subplots were established and pollution sensitive lichens transplanted. Preliminary results show no visible damage to any of the plants.

Report: Further information is available from the Canadian Forestry Service, Victoria.

Analysis and Interpretation of Stream and Precipitation Chemistry for the ARNEWS Plot at the UBC Research Forest

Data collected since 1971 at the University of British Columbia (UBC) Research Forest, near Haney, British Columbia, suggest that the soils and vegetation are absorbing most of the incoming hydrogen ions and significant amounts of hydrogen or aluminum ions are not being leached into the stream. However, increased atmospheric hydrogen ion inputs could stress the system, resulting in the release of these ions.

Nitrate and sulphate concentrations in precipitation have increased with time, as has nitrate in streamwater.

Report: Further information is available from the Canadian Forestry Service, Victoria.

8. JOINTLY MANAGED ACTIVITIES

8.1 EMISSIONS AND CONTROL TECHNOLOGY

Inventory of Air Pollution in British Columbia

The Inventory Management Division of Environment Canada and the Province of British Columbia have commissioned an inventory of emissions for 1985 for all permitted sources in the province, excluding the Greater Vancouver Regional District. This inventory of emissions includes the following pollutants: sulphur dioxide, nitrous oxides, carbon monoxide, hydrocarbons, cadmium, lead, and vanadium.

In addition, Environment Canada is conducting the inventory of emissions into ambient air from area sources and mobile sources for British Columbia, excluding the Greater Vancouver Regional District (GVRD). A report is expected by mid-1987. The activities of the GVRD are documented separately, below.

Report: A preliminary report has been prepared for use by the Technical Committee. Information is available from: Environmental Protection, Environment Canada in West Vancouver, British Columbia; and the Ministry of Environment and Parks in Victoria, British Columbia.

Inventory of Air Pollution in Greater Vancouver

The Greater Vancouver Regional District, in collaboration with Environment Canada, and with technical assistance from the Province, conducted a detailed inventory of emissions for 1985. This work, which complements the province-wide inventory (above), is to be completed in 1987.

Report: Reports are not yet available.

8.2 AIR QUALITY AND DEPOSITION

Target Loadings for Acidic Deposition in Western Canada

In late 1985, the National Research Council was contracted to prepare a document which would survey the scientific basis of the acid deposition target loading concept, discuss the selection of parameters on which its application may be based, recommend on the appropriate target loading for the western Canada region, and document the availability of data bases for these parameters. The National Research Council contracted ESSA Environmental and Social Systems Analysts Ltd. and Concord Scientific Corporation to assist in the report preparation.

Report: A draft of the final report has been received. Final report will be available by mid-1987 from the Technical Committee members listed at the beginning of this Annual Report.

8.3 SURFACE WATERS

Lake Sensitivity Mapping for Western and Northern Canada

Maps of Western and Northern Canada, depicting lake sensitivity to acid precipitation, have been compiled from individual maps prepared for western provinces and the Northwest Territories. The map scale is 1:7,500,000. Maps are being drafted in preparation for printing. An accompanying report has been prepared describing background to the project, methods used, and general observations on sensitivity.

Report: The overview maps and a report will be available by mid-1987 from the Technical Committee Members listed at the beginning of this Annual Report.

Cree Lake LRTAP Monitoring Study

Water Quality Branch, Environment Canada, and Saskatchewan Environment began a study in 1986 on five small lakes in the Cree Lake area of Saskatchewan to: (1) assess the spatial variability within the lake cluster; (2) determine the seasonal patterns including the effect of snowmelt on lake chemistry; (3) assess the effectiveness of Saskatchewan Environment's monitoring program with respect to the best time to collect samples; and (4) conduct biological surveys of the lakes in support of the chemical program and provide baseline information. This is the first year of a three year study.

Report: Further information is available from the Water Quality Branch, Northwest Region; Environment Canada, Regina; and, Saskatchewan Environment and Public Safety.

8.4 SOILS AND GEOLOGY

Sensitivity of Western and Northern Canada Soils and Geology to Acidic Inputs

Maps of Western and Northern Canada depicting soil and geology sensitivity to acid precipitation have been

compiled from individual maps prepared for western provinces, Yukon Territory, and the Northwest Territories. The map scale is 1:7,500,000. Maps are being drafted in preparation for printing. An accompanying report has been prepared, describing background to the project, methods used, and general observations on sensitivity.

Report: Further information is available from the British Columbia Ministry of Environment and Parks.

8.5 VEGETATION

No activities were conducted in this area.

8.6 HEALTH

Long-Range Transport of Air Pollutants — Health Effects

A joint epidemiological study is being conducted by Health and Welfare Canada and Saskatchewan Environment and Public Health on elementary school-aged children to assess the potential risk to human health from the long-range transport of air pollutants. The study will be extended to the end of 1987 to gather further data.

Five communities have been selected in Ontario in an area affected by the long-range transport of air pollutants. Five communities have also been selected in Saskatchewan, an area that is not affected by the long-range transport of air pollutants. The risk to human health will be determined by comparing the data collected from the two areas. The study includes ambient air monitoring of sulphur dioxide, ozone, nitrogen dioxide, carbon monoxide, suspended particulates, and inhalable particulates in each area.

Report: Further information is available from Health and Welfare Canada and the Air Quality Branch, Saskatchewan Environment and Public Health.

9. INDUSTRY AND INSTITUTION ACTIVITIES

9.1 BRITISH COLUMBIA

Environmental and Spatial Statistics

THE SOCIETAL INSTITUTE FOR THE MATHEMATICAL SCIENCES (SIMS)

The University of British Columbia (UBC) is participating in a $1-million study on acid rain. Acid rain is an environmental problem which occurs in North America, Europe and other parts of the world. Involved with UBC in the three-year project, financed by the U.S. Environmental Protection Agency, are SIMS, Stanford University, and the Rand Corporation. The SIMS team aims to estimate the naturally-caused levels of acid rain as a fraction of the total amount present in any location. In particular, statistical methods are being developed to allow for the detection of the impact of acid rain, to measure trends, to map acid rain deposition levels, and to determine how those levels vary from region to region.

A seminar series at UBC facilitated the exchange of knowledge on acid rain among researchers in government, industry and universities. Several of the 1985/86 visiting speakers have participated to varying extents in the acid rain research program.

Reports on the activities of the Society are included in the sections below.

Acid Rain Data

Battelle's Pacific Northwest Laboratory has made available to the University of British Columbia a considerable amount of acid rain data. These data, obtained from the nine station MAP3S/PCN monitoring network in the Northeastern U.S. 1976 through 1982, have been extensively analyzed at UBC. A description of the MAP3S/PCN data-set for internal users is available.

Report: The report listed below is available through J. V. Zidek, Department of Statistics, University of British Columbia. MAP3S/PCN Acid Rain Precipitation Monitoring Data Base (R. Gentleman, A. R. Olsen and J. V. Zidek).

Solar Radiation

The SIMS group has obtained daily data for solar radiation at twelve stations in the Lower Mainland of British Columbia. These data follow a Gaussian distribution fairly accurately and there are no missing values. Thus the data provide an excellent testing ground for new methods.

Because of the nearly ideal character and condition of these data, methods being developed for acidic deposition monitoring could be tested on a preliminary basis with assurance that any perceived anomalies were not the product of the data themselves. Results obtained so far gave confidence in the methodology, and follow-up testing on acid rain data is now underway. The particular method that has undergone assessment is designed to yield realistic estimates of spatial correlation patterns in such fields as that of pH in rainfall.

Report: A report is in preparation, and will be available through J. V. Zidek, Department of Statistics, University of British Columbia.

Water Quality Data

The Water Management Branch of the Ministry of Environment and Parks, Province of British Columbia, has provided a data-set for lakes in British Columbia. This includes the number of lakes, and simultaneous measurements of water chemistry and aquatic biota.

A major new data set obtained in 1985/86 derives from Phase I of the Eastern Lake Survey (conducted in the fall of 1984) as part of the EPA's National Surface Water Survey which is part of the National Acid Precipitation Assessment Program. The objectives of Phase I were:

- to determine the percentage and location of acidic lakes and lakes with low acid neutralizing capacity in potentially sensitive areas of the eastern U.S., and
- to determine the chemical characteristics of lake populations in sensitive areas of the eastern U.S. and to provide the data base for selecting lakes for further study.

Report: A report is not yet available. Further information can be obtained from J. V. Zidek, Department of Statistics, University of British Columbia.

Concentrations Models

Properties of a stochastic differential equation model have been developed for the concentration of a particular compound, given the rainfall intensity process and the emissions of a compound into a fixed volume air package. The parameters of the model can be estimated by maximum likelihood. These estimates are consistent and asymptotically normal.

Report: Models for Transportation and Deposition of Atmospheric Pollutants (P. Guttorp). This report is available through J. V. Zidek, Department of Statistics, University of British Columbia.

Rainfall Models

The SIMS group has been concerned with rainfall modelling, particularly with the important class of models, Neyman and Scott. Some of the published work also relates to the transportation and deposition of atmospheric pollutants.

The correct method of fitting rainfall models to the derived discrete time binary process of rainfall has been investigated. The impact of using discrete data to fit continuous time models and the validation of a continuous time model by fitting the corresponding discrete model on differing time scales are illustrated in work which was published as a technical report in 1986.

Report: The reports listed below are available through J. V. Zidek, Department of Statistics, University of British Columbia.

On Binary Time Series Obtained from Continuous Time.

Compatibility of Continuous Rainfall Occurrence Models with Discrete Rainfall Observations (E. Foufoula-Georgiou and P. Guttorp).

Modelling Rainfall Using Event-based Data (P. Guttorp).

Assessment of a Class of Neyman-Scott Models for Temporal Rainfall (P. Guttorp and E. Foufoula-Georgiou).

Testing Models

The important problem of testing hypotheses when, as is typically the case in the spatial setting, errors are autocorrelated has been treated. The results apply to the problem of testing for environmental impacts of such things as the start up or the closure of a power plant.

Report: The report listed below is available through J. V. Zidek, Department of Statistics, University of British Columbia.

Hypothesis Tests for Regression Models with Autocorrelated Errors (S. P. Millard and P. Tuttorp).

Expert Consensus as a Method for Setting Pollution Control Guidelines

In setting guidelines for regulation it is becoming increasingly common to convene a group of experts to search for a consensus. They may be asked to reach a consensual decision. A celebrated, normative, equilibrium solution to such a group decision problem is provided by Nash's theory: the equilibrium solution maximizes a certain functional of the individual utility functions. Software has been developed to plot for the case of $n = 3$ experts, the region of achievable utility vectors when a common estimate of a vector of multinormal mean levels is at issue. From this it is possible to see precisely how dissensus (when the equilibrium becomes a randomized decision rule) is reached as preferences and opinions of the experts diverge.

An expert's opinion about the possible states of nature, for example, the uncertain site of a point of impact by a pollutant, or its concentration may be quantified as a distribution. A formula for combining these distributions, and hence their underlying opinions, has been derived. The formula, a geometric average with variable averaging weights, is a consequence of the natural requirement that if any A is jointly regarded by the group as more likely than B, then it would remain so even if it is learned that E, an event which includes both A and B as subevents, has occurred.

Report: The reports listed below are available from J. V. Zidek, Department of Statistics, University of British Columbia.

Conditionalization and the Logarithmic Opinion Pool (S. Weerahandi and J. V. Zidek).

Likelihood Dominance and Group Belief Formation (C. Genest, J. V. Zidek and S. Weerahandi).

Graphical Representations of Opinion Surfaces in Multi-agent Normal Mean Estimation (M. A. Wells and J. V. Zidek).

Modelling of the Deposition Process

A deposition process may be regarded as carrier plus noise, where the carrier = model + smooth, and the smooth is locally approximable by its Taylor expansion. Bayes and empirical Bayes methods of estimating the smooth have been extensively studied for Gaussian deposition fields. Now in hand are methods using this approach for interpolating and predicting a univariate time series or several independent time series as well as for estimating quantiles and generating (credibility) intervals for forecasting. Reports on these results were published in 1985 and 1986. As well, the work was extended to the space-time context.

Report: The reports listed below are available from J. V. Zidek, Department of Statistics, University of British Columbia.

Analyzing Locally Smooth Processes by Bayesian Nonparametric Methods (S. Weerahandi and J. V. Zidek).

Analysis of Multiple Time Series by Bayesian and Empirical Bayesian Nonparametric Methods (S. Weerahandi and J. V. Zidek).

Survey of Selected Nonparametric Smoothing Methods (H. W. Ma).

A Bayesian Nonparametric Univariate Smoothing Method, with Applications to Acid Rain Analysis (H. W. Ma, H. Joe, and J. V. Zidek).

Spatial Dispersion Model

A new method for global nonparametric estimation of spatial dispersion has been developed. It utilizes a scaled-metric scaling approach and biorthogonal grids. Software for computing the grids has been written, and theoretical development of the scaling method is now complete and available at UBC.

Report: A report is in preparation and is available from J. V. Zidek, Department of Statistics, University of British Columbia.

Space-Time Model

Eynon and Switzer derived a space-time model for the acidity of precipitation using two years of data from the Electric Power Research Institute (EPRI) nine-station monitoring network. An attempt to validate this model on five years of data from the MAP3S/PCN nine-station monitoring network has been carried out. The results indicate that this model fails to capture many of the features of this independent data set. As part of the investigation, many details concerning the structure of the data have been identified. A report on this investigation was produced in 1985/86.

A follow-up analysis on this space-time problem consisted of a wide-ranging analysis of the data set with the goal of developing a useful spatial-temporal structure. The very thorough analysis reveals a surprising lack of structure, leaving the view that additional co-variate data would be needed to account for the variability of acid deposition.

Report: The reports listed below are available through J. V. Zidek, Department of Statistics, University of British Columbia.

An Attempted Validation of the Eynon-Switzer Model for the Variability of Rainfall Activity (D. Nhu Le, and A. J. Petkau).

An Exploration of Structure in the pH Levels of the MAP3S/PCN Data Set (D. Nhu Le, and A. J. Petkau).

Estimating Extreme Values

The ability to estimate extreme values of atmospheric contaminants is vital in any problem of regulation, control and abatement. Research in this direction has been carried out. The problem is to estimate the quantity of the maximum of a sequence of N random variables (say, a future time series) given that no observations have been obtained. Research has been done in the case where the random variables are assumed independent and identically distributed; two parametric approximations from asymptotic extreme value theory were compared. Future research will deal with the case of weakly dependent observations, this being a more realistic assumption for practical application.

Report: The report listed below is available through J. V. Zidek, Department of Statistics, University of British Columbia.

Estimation of Quantities of the Maximum of N. Observations (H. Joe).

Air Quality and Deposition

Ozone Biomonitoring in the Fraser Valley

In the growing seasons of 1985 and 1986, tests were conducted to determine whether a variety of tobacco, prone to visible tissue damage by ozone, might be used as an indicator of yield reduction in crops exposed to ozone. Part of the investigation took place in an experimental outdoor field at the University of British Columbia (UBC) where it was possible to regulate the concentration of ozone in the air. Another part of the investigation took place at 12 locations in the Fraser Valley. Five of these sites were adjacent to stations monitoring ozone in ambient air.

The results of biomonitoring at the UBC experimental field indicate the existence of a significant relationship between cumulative injury to the tobacco plants and reduced yield of potato and pea plants. This finding suggests that biomonitor plants such as the tobacco variety Bel W-3 may be used in agricultural areas as an indicator of yield for these crops.

The results of biomonitoring at the 12 biomonitoring sites in the Fraser Valley in 1985 differed from those in 1986: tobacco plants sustained injuries caused by ozone in 1985 but they had few, if any, injuries in 1986. These findings are consistent with the different climatic conditions during these two growing seasons. In 1985, the hot dry weather favoured the formation of ozone, whereas in 1986 the weather was not conducive to ozone formation. By combining the findings from the UBC experimental field and from the 12 biomonitoring sites in the Fraser Valley, it is reasonable to infer that there were significant reductions in the yield of potato and pea crops in 1985, but minimal reductions in 1986.

Report: This project is a portion of the Ph.D. research being conducted by G. Brown under the direction of V. Runeckles, Department of Plant Science, UBC. The research was supported in part by Environment Canada (1985) and by Agriculture Canada (1986).

Vancouver Oxidants Study: Air Quality Update (1982-1984)

Ozone episodes occurring between 1982 and 1984 in the Greater Vancouver Regional District (GVRD) were identified and the meteorological characteristics associated with the ozone episodes were reviewed. Similar analyses of the ozone episodes in the period from 1978 to 1981 were conducted in a previous study. Both reports were prepared by Concord Scientific Corporation under contract to Environment Canada and are available from the Conservation and Protection, Environment Canada.

Examination and analyses of the GVRD ambient air quality data for the 1982-1984 period showed a marked decrease in the annual mean ozone concentrations. The levels of nitrogen oxides showed a parallel decline when expressed on an area-wide basis but total hydrocarbon levels did not show similar declines.

Ozone episodes (defined in terms of the number of consecutive hours above the national maximum acceptable air quality objective for the one hour average, simultaneous occurrence at 3 or more stations and persistence over three or more consecutive days), declined markedly since 1982.

Meteorological characteristics of ozone episodes were examined for individual episodes as well as by analysis of a five year (1979-1984) synoptic climatology of the ozone season (May to September). Although no particular synoptic type showed marked correlation with high ozone levels, the highest mean daily maximum ozone concentration and the greatest number of ozone episodes occurred when a slack pressure gradient prevailed over the GVRD, identifying light winds as a probable prerequisite for high ozone levels.

Back trajectories for seven of the episodes that occurred between 1982 and 1984, showed inconclusive evidence for long-range transport of pollutants as a major contributor to high ozone levels in the GVRD.

Although the meteorological characteristics of elevated ozone levels in the GVRD were further clarified in this study, there was no conclusive evidence to account for the marked decline in ozone levels in the 1982-1984 period compared with the 1978-1981 period. The understanding of the observed oxidant air quality in the GVRD will be enhanced by the ongoing compilations of emissions inventories of oxidant precursors and also by attempts to model photochemical oxidant formation on the GVRD.

Report: This research was conducted by Concord Scientific under the direction of Claude Davis.

Statistical Model for Predicting Ozone Concentrations

Research is currently being conducted within the University of British Columbia Department of Geography by D. G. Steyn and Mr. S. M. Robeson. Their work focuses on the spatial and temporal variability of surface level ozone in the Lower Fraser Valley of British Columbia where extremely high concentrations of ozone have been observed.

The research is directed towards the development of statistically based models for predicting ozone concentrations. Eight years of hourly observations are drawn from a network of air quality and meteorological monitoring stations operated by the Greater Vancouver Regional District and the British Columbia Ministry of Environment and Parks.

A model which describes the annual cycle of ozone concentrations has been developed. Concentrations reach a maximum in mid-summer when solar radiation is strong and anticyclonic conditions persist. In order to account for the seasonal periodicity, a second order polynomial is fitted to the data. A strongly autocorrelated sequence of data remains. A simple first order auto-regressive equation removes the serial correlation, leaving a normally and independently distributed sequence with a mean value of zero. Hence, the ozone concentration on Julian day 't', x_t, may be described by

$$x_t = \exp [\ f(t,t^2) + r\, e_{t-1} + a_t\ ] + K$$

where $f(t,t^2)$ represents the polynomial, 'r', is the first order autocorrelated coefficient, a_t is a normally and independently distributed random variable, e_{t-1} is the previous day's residual and 'K' is a constant. This annual model provides valuable insight into the temporal variability of ozone concentrations in the region. Current research is involved with a search for relations between ozone concentrations and precursor pollutants as well as selected meteorological variables.

Report: No report is available at this time, but the research results are to be published and will be available from the Department of Geography, University of British Columbia.

Vegetation

Effects of Ozone on Vegetable Crops

Studies commenced in 1985 on the effects of ozone on yields of major vegetable crops grown in the Fraser

Valley. In 1985, plots of peas, beans, carrots and broccoli were exposed to ambient and ozone-enriched air under true field conditions, using the Zonal Air Pollution System (ZAPS) on the University of British Columbia campus. Clear evidence was obtained for adverse effects on yield as a result of exposures to increased ozone levels.

In 1986, the system was modified to create twelve unique sets of test conditions characterized by distinctly different distributions of ozone concentration during the growing season. Crops of potatoes and processing peas grown under these different regimes sustained significant decreases in yield as a function of the number of days in the growing season that the ozone concentration exceeded 25 parts per billion (ppb). These decreases in yield were also found to be a function of the mean ozone concentration during the twelve daylight hours throughout the growing season.

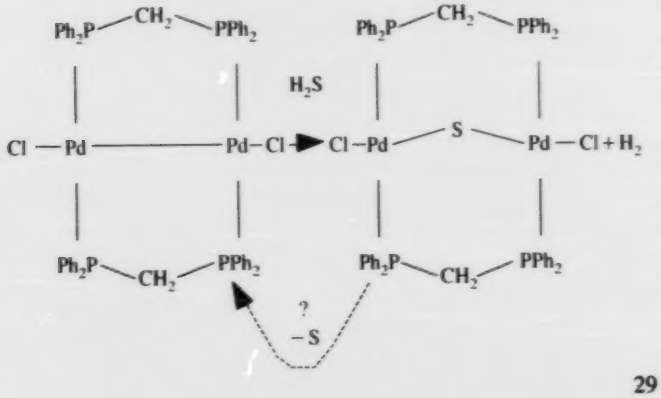
The yield reductions observed are well correlated with the levels of leaf injury observed on tobacco biomonitor plants grown through the season and exposed to four of the twelve ozone distributions (See separate report: Air Quality and Deposition, above).

Report: This research is part of the M.Sc. program of Elaine Wright under the direction of V. Runeckles, Department of Plant Science, UBC. The research was supported by the British Columbia Ministry of Environment in 1985 and 1986, and in part by Agriculture Canada in 1986.

Control Technology

Pollution Control Technology for Hydrogen Sulphide

A complex of palladium, illustrated below, has been found to react with hydrogen sulphide, which is a contaminant in industrial gas streams. The sulphur is abstracted and finishes up as a bridging atom between the palladium atoms, while the residual hydrogen is generated quantitatively.



This reaction, which converts a pollutant (hydrogen sulphide, H_2S) into an energy source (hydrogen gas, H_2), is clearly of considerable potential. Attempts are being made to regenerate the starting palladium reagent via loss of sulphur from the palladium product; such chemistry would lead to catalytic conversion of hydrogen sulphide to hydrogen gas and elemental sulphur.

Report: Reports are not yet available, but some are in preparation. Further information can be obtained from B. R. James, Department of Chemistry, University of British Columbia.

Surface Waters

Acid Deposition in Small Forested Drainages

Precipitation and streamwater chemistry have been monitored more or less continuously since 1970 in several small forested drainages located 40 km east of Vancouver, in south western British Columbia. This monitoring is part of a continuing study of the effects of forest management practices on the nutrient budgets of small drainages, and the water quality of streams.

Precipitation in the area is relatively acidic, with mean annual pH values of 4.5 to 4.9, and anion chemistry dominated by sulphate ion ($SO_4^{=}$). The second most abundant ion in the rainfall is nitrate (NO_3^{-}).

Stream water in the area generally contains low quantities of dissolved chemicals and has a relatively low buffer capacity of 20-70 micro moles per litre. However, acid precipitation has not recently caused any significant impacts in the chemistry of stream water. The pH of stream water has always been 6.1 relative units, or greater, and decreases in pH during storm events are on the order of 0.1 to 0.4 relative units.

Concentrations of dissolved aluminum (Al^{+++}) are not as great as are typically found in acidified waters, and most of the aluminum is complexed with organic compounds, (making the aluminum relatively less toxic to aquatic organisms. Ed.).

Analysis of the hydrogen ion budgets within the drainages indicates that the soils are being acidified; but, the rate at which hydrogen ions are generated within the drainages exceeds the rate of supply by the atmosphere.

Acidification of the soil-vegetation component of the drainages causes the release of basic cations. These cations moderate the impact of acidification on the stream water, reducing the severity of impact.

Report: Further information is available from M. C. Feller, Faculty of Forestry, University of British Columbia.

Effect of Low pH on the Growth of Larvae of a Caddisfly

Larvae of the caddisfly *Clistoronia magnifica* (Trichoptera: Limnephilidae) are found to grow more rapidly than usual when allowed to feed on leaf litter conditioned by the growth of fungi at low pH. Conditioning of the leaves at low pH may increase the availability of carbohydrates because of increased fungal biomass and additional modification of the leaf matrix by fungal enzymes. The increased fungal biomass is believed to result from enhanced activity of the fungal enzymes involved in the decomposition of organic material in the leaves. These findings are based on research by Mr. K. van Frankenhuyzen and Dr. Glen Geen, at Simon Fraser University.

Report: Further information is available from the Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia.

Fish Physiology

Effects of low pH on the physiology of salmon and trout, at various phases in their life history, are being investigated by Dr. B. A. McKeown and his associates at Simon Fraser University. The impetus for these studies is to understand the potential impact of acid deposition on important species of salmon and trout in British Columbia, and to examine the role of calcium in water in mitigating ill effects. Investigations, discussed separately below, focus on four areas: 1. the capacity of fishes to regulate ions in their blood, 2. the ability of smolts to withstand the stress of adaptation in sea water, 3. the survival of eggs and alevin at low pH, and 4. the blood chemistry of rainbow trout in calcium enriched fresh water.

Blood Chemistry

Regulation of blood chemistry was studied in parrs and smolts of juvenile coho salmon prior to their entry into sea water. Exposure to low pH caused changes in blood chemistry, and reductions in the activity of enzymes in the gill epithelium related to the flow of ions across the gill. This research was conducted jointly by Powell and McKeown in 1986.

Report: The following report is available from the Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia:

The effects of acid exposure on the ion regulation and seawater adaptation of coho salmon (*Oncorhynchus kisutch*) parrs and smolts.

Gill Epithelium

Damage to the gill epithelium is expressed differently in cohorts of different sizes, during salt water challenges. When forced to adapt to sea water, small cohorts of coho salmon have higher mortality rates than large ones. This research was conducted jointly by McKeown, Geen, Watson, Powell, and Parker in 1985 (see Report, below).

Report: The following report is available from the Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia:
The influence of (fish) size on ion regulation and sea-water survival of acid-exposed coho salmon smolts (*Oncorhynchus kisutch*).

Incubation at Low pH

Survival of salmon eggs and alevin at low pH (4.5 - 4.0) was reduced. Also, hatching was delayed, and the efficiency of the conversion of yolk to tissue in yolk-sac alevin was reduced. These effects were more pronounced when eggs were fertilized at low pH, and when sexually mature adults (kokanee salmon) were exposed to low pH prior to spawning. This research was conducted jointly by Parker and McKeown in 1986.

Report: The following report is available from the Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia:
The effects of low pH on egg and alevin survival of kokanee and sockeye salmon, (*Oncorhynchus nerka*).

Vitellogenin and Calcium

Low pH has some influence in the concentration of vitellogenin in plasma of rainbow trout. In female fish, environmental calcium increased the calcium content of bone. However, there was no evidence of bone demineralization in trout of either sex exposed to low pH. This research was conducted jointly by Parker and McKeown in 1986.

Report: The following report is available from the Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia:

Effects of pH and/or calcium-enriched freshwater on plasma levels of vitellogenin and Ca^{++}, and on bone calcium content during exogenous vitellogenesis in rainbow trout (*Salmo gairdneri*).

Biology of Lakes and Streams

Impact of Lake Acidification

The impact of lake acidification on plankton communities, and the interactions between phytoplankton and zooplankton, was studied experimentally by Mr. David

Marmorek, Department of Zoology, Faculty of Graduate Studies, University of British Columbia. Field experiments were carried out *in situ*, in eight large plastic enclosures (28,000 L), in Eunice Lake, which is situated in the Coastal Range Mountains of British Columbia.

Acidification with sulphuric acid (H_2SO_4) to pH 5.6 had little effect on zooplankton, phytoplankton, or transparency of the water column. Enrichment with fertilizers (NH_4NO_3, and H_3PO_4), without acidification, increased the biomass of the phytoplankton and the zooplankton communities. Acidification combined with enrichment, caused changes in the biological-limnological cycling of ammonium nitrate (NH_4NO_3) which was reflected by a reduction of the pH to 5.4.

These chemical changes within the enriched and acidified enclosures caused high rates of mortality in the predominant species of zooplankton, *Daphnia rosea*. Subsequently, the phytoplankton biomass, as estimated by measurements of chlorophyll-*a*, increased 6-9 fold above levels in enclosures that were fertilized but not acidified. The zooplankton community exhibited major changes in the species composition, size structure, and biomass. The initial increase in phytoplankton biomass, and the subsequent fluctuations, seemed to result more from changes in the rate of grazing by zooplankton caused by low pH, than by direct effects of acidification on phytoplankton.

A second enclosure experiment involved acidification of unenriched enclosures over a ten day period to pH 5.5, 5.0, or 4.5, followed by constant pH conditions for seven weeks. Mean zooplankton biomass decreased by 20 per cent, 63 per cent, and 74 per cent (respectively). *D. rosea* showed similar acid tolerance during the first experiment.

Report: The research has been completed and is available as a thesis from the University of British Columbia. Further information is available from ESSA Environmental and Social Systems Analysts Ltd.

Impact of Stream Acidification

The impact of stream acidification on lotic invertebrates was studied experimentally by Mr. David Bernard, Department of Zoology, University of British Columbia. Invertebrates in a second order headwater stream near Vancouver, British Columbia, were exposed to hydrochloric acid, or aluminum chloride ($AlCl_3$), or both. Acidity in the stream increased from pH 6.9-7.0 to pH 5.8-6.0; aluminum concentrations increased from less than 0.1 mg/L to greater than 1.0 mg/L.

These chemical changes in the lotic environment were associated with a four-fold increase in the rate of invertebrate drift, as measured by the number of organisms trapped per unit time by sample nets. When the stream was acidified continuously for 48 hours, the addition of aluminum ions to the water produced an even greater response. Laboratory studies confirm that these behavioural responses are associated with the aluminum and the acid, and are not caused by the chloride ions.

These studies demonstrate that increased dissolved aluminum concentrations intensify biological responses to acidification. Experimentally manipulating this community produced results closely resembling those obtained in similar studies for areas currently affected by acidic precipitation. The major difference in results between studies is that invertebrate communities previously unexposed to acidification contain more species sensitive to mild acidification. These latter animals are particularly sensitive to elevated concentrations of dissolved aluminum.

Report: The research has been completed and is available as a Master's Thesis from the University of British Columbia Library. Further information is available from ESSA Environmental and Social Systems Analysts Ltd.

9.2 ALBERTA

Compressor Station Stack Design Study

Current models do not accurately predict the concentration of oxides of nitrogen in the vicinity of natural gas compressor stations. The objective of this study was to evaluate the prediction capabilities of several other models. After assessing a number of models, the study concluded that they offer no significant improvement over those already in use.

Report: A final report is available from the Canadian Petroleum Association.

Incineration of Selected Waste Process Filters

During late 1984 and 1985, research was undertaken to assess the feasibility of incinerating selected waste process filters. A key component of the research was the examination of the air emission resulting from the incineration of various filter types.

Report: A report is available from the Canadian Petroleum Association.

Alberta Government and Industry Acid Deposition Research Program

The government-industry acid deposition research program (ADRP) is a multi-million dollar program beginning its fifth year in 1987. The agencies involved in this

program include the Alberta Government, the Canadian Petroleum Association, Alberta's electrical utilities, and the Energy Resources Conservation Board. The program's overall objective is to assess the environmental impact of acid-forming gases in Alberta. Current work includes two individual projects:

1. a 42-month Biophysical Research Program, Critical Point I, to be completed in the fall of 1988;
2. a feasibility study into occupational health for gas and thermal plant workers.

In 1986 the project on administration and management of the Southwest Alberta Medical Diagnostic Review was completed.

Report: World literature reviews and the medical diagnostic review are available from the ADRP office.

The Effects of Atmospheric Pollutants on Corrosion Rates of Metals — A Literature Review

This project was designed to determine whether air pollutants cause premature rusting of metals and to identify variables which accelerate or decelerate corrosion processes. To accomplish these objectives, a literature review of published and unpublished data, with emphasis on that relevant to Western Canada, was conducted.

Report: A final report is available from the Canadian Petroleum Association.

9.3 SASKATCHEWAN

Emissions and Control Technology

Saskatchewan Power Corporation Monitoring Activities at Poplar River (Coronach) and Boundary Dam (Estevan) Power Stations

Two stations continuously monitoring ground level concentra tions of sulphur dioxide are located at the Canada/US International Boundary. One is located south of the Poplar River Power Station and the other south of the Boundary Dam Power Station. Emissions at the Poplar River Power Station are continuously monitored for opacity, sulphur dioxide, and nitrogen oxides concentrations. Surface waters in the vicinity of the Poplar River, Boundary Dam, Queen Elizabeth and Estevan power stations are monitored and analyzed for pH, sulphates, nitrates, and alkalinity.

Report: Further information is available from the Saskatchewan Power Corporation and Saskatchewan Environment and Public Safety.

Saskatchewan Power Corporation Agricultural Monitoring Program — Poplar River Power Plant

As part of this program, the Saskatchewan Research Council measured the cumulative impact of sulphur dioxide as measured by lead peroxide samplers (sulphation levels) at thirty-six sites. Rainfall samples at six sites were collected and analyzed for pH, sulphate, nitrate, calcium, magnesium, potassium, sodium, chloride and specific conductance. Soil chemistry was monitored for pH and sulphur content, and wheat crops were analyzed for chlorophyll-*a*, chlorophyll-*b*, nitrogen and sulphur.

Report: Further information is available from the Saskatchewan Power Corporation.

SO_2/NO_x Emission Reduction Program

Further testing was conducted in May-June 1986 to optimize the performance of the sorbent injection/staged combustion system on Unit 4 at the Boundary Dam Power Station. Testing included the use of both calcium hydroxide and calcium carbonate sorbents. Testing is continuing at the present time and will include an evaluation of economizer inlet injection as well as the use of different sorbents and different methods of hydration.

Report: Reports and information are available from the Director, Coal and Gas Research and Development Centre, Saskatchewan Power Corporation.

Kinetics of Sulphur Removal in Boilers and Baghouses Using Calcium Sorbents

This project summarizes the results of Research and Development studies of the mechanisms and kinetics of high temperature sulphation reactions in boilers and low temperature sulphation reactions in baghouses and electrostatic precipitators. For the sulphur removal in boilers, the report shows that a product layer, diffusion control model closely approximates the experimental data obtained in pilot-scale combustion rigs and utility tests. For sulphur removal in baghouses, the report shows the importance of humidification and the close approach to the flue gas saturation temperature for efficient sulphur dioxide removal. Also, the kinetic studies elaborate on the effects of important design and operating variables, and sorbent characteristics on sorbent utilization.

Report: A report is available from the Director, of the Coal and Gas Research and Development Centre, Saskatchewan Power Corporation.

Assessment of Sorbents for Reducing Sulphur Dioxide Emissions

Approximately thirty sorbents were examined for a variety of chemical and physical properties relating to their ability to remove sulphur dioxide from power plant flue gas. From these studies, two currently available limestone and three hydrated lime products were recommended for pilot-scale tests for Saskatchewan Power Corporation field tests.

Report: A report is available from the Director, of the Coal and Gas Research and Development Centre, Saskatchewan Power Corporation.

Development of Improved Reagents for SO_2 Capture in Dry Injection Systems

Laboratory tests and experimentation are continuing on development of improved calcium-based reagents for abatement of sulphur dioxide emission. Work is in progress.

Report: Information available from Director, Coal and Gas Research and Development Centre, Saskatchewan Power Corporation.

Monitoring at Amok Ltd. Uranium Mine, Cluff Lake

The average sulphation levels are determined on a monthly basis at 23 sites around the mine using lead peroxide plates.

Report: Data summaries are available from Amok Ltd. and Saskatchewan Environment.

Monitoring at Eldor Mines Uranium Mine, Rabbit Lake

Eldor Mines continuously monitors ground level concentrations of sulphur dioxide at one site.

Report: Data summaries are available from Eldor Mines and Saskatchewan Environment.

VEGETATION

Comparative Injury to Saskatchewan Vegetation Caused by Acidic Precipitation

The objectives of this research are: (1) to compare the sensitivities of plant tissues to acidification, primarily by use of the membrane leakage test, and (2) to investigate the mode of injury from excess acidity, including the direct effects of hydrogen ions, and the synergistic effects of other ions. This study is expected to be completed in 1989.

Report: Further information is available from R. E. Redmann, Department of Crop Science and Plant Ecology, University of Saskatchewan.

9.4 MANITOBA

Monitoring in Thompson

A permanent station continuously monitoring ground level concentrations of sulphur dioxide is northwest of the Inco non-ferrous smelter facility located between the plant and the town of Thompson. A mobile station is used during the spring, summer, and early fall (during the growing season) to monitor sulphur dioxide concentrations from other directions.

In addition to measuring ground level concentrations of sulphur dioxide, there is a meteorological program to regulate the smelter production so that acceptable concentrations of sulphur dioxide are maintained under differing dispersion conditions.

Satellite imagery is being used to detect and map vegetation changes in the Thompson area. Maps have been prepared for 1973, 1978, and 1983.

Report: Data Summaries are available from Inco Limited.

Removal of Sulphur — Inco

A research program is being conducted by Inco Ltd., Manitoba Division, on the reduction of sulphur in the concentrate being smelted. The program, which is sponsored under the Canada/Manitoba Mineral Resources Development Agreement, is investigating techniques for increased removal of high sulphur pyrrhotite in the mill with minimization of metal losses.

Report: This is an ongoing program. Further information is available through Inco Limited.

Monitoring in Flin Flon

Three stations continuously monitor ground level concentrations of sulphur dioxide within 5.0 kilometres (km) of the 250 metre high main stack of the non-ferrous smelter facility. A high volume sampling program measuring airborne particulate levels for heavy metal concentration determination was operated at two sites within 5.0 km of the main stack up to January 1985. Dustfall had also been measured at two sites within 5.0 km of the main stack up until January 1985. The dustfall samples were used to determine particulates for total solids, dissolved solids, and ignition loss.

Report: Data summaries are available through Hudson Bay Mining and Smelting Company, Ltd.

Removal of Sulphur — Hudson Bay Mining and Smelting

Several studies to research and develop process technology have been done, or are currently underway, to reduce emissions from the zinc and copper producing operations of Hudson Bay Mining and Smelting Company at Flin Flon. These studies have been funded under Canmet programs, and the Canada/Manitoba Mineral Resources Development Agreement.

Report: These are ongoing programs. Further information is available through Hudson Bay Mining and Smelting Company, Ltd.

10. ANNUAL DEPOSITION OF SULPHATE AT SAMPLING STATIONS IN WESTERN CANADA

SULPHATE DEPOSITION TABLES

Calculation of Deposition at CANSAP Stations

Depositions from CAPMON stations are from data published in *CAPMON Precipitation Chemistry Data Summary 1983-1984*, Report AQRB-86-001-M, March 1986, published by the Atmospheric Environment Service, Downsview, Ontario. Deposition data from the CANSAP stations have not been published but were calculated from available concentration data. Depositions were calculated for the last three years for which data are available and during which the CANSAP protocol was unchanged. Years for which fewer than ten months of data were available were omitted. For years with ten or more months of data, depositions were calculated using the standing gauge precipitation-weighted concentration and *total annual* precipitation. The CANSAP data are included since they are the best available for the period.

Key to Symbols

- no data, or insufficient data, or data not yet available

1 CANSAP station

2 CAPMON station

3 PROVINCIAL STATION

( ) values in parentheses have been corrected for sea salt

e estimated value

* annual deposition based on eleven months of data. Data for November seemed to be erroneously high and were excluded from the set.

Table 1. Annual Deposition of Sulphate at Sampling Stations in British Columbia

STATION	Annual Deposition of Sulphate ($SO_4^=$) kilograms per hectare				
YEAR	1982	1983	1984	1985	1986
Agassiz	—	—	—	11.4 (10.4)	12.5 e (11.2)e
Cranbrook	—	—	—	—	—
Dawson Creek	—	—	—	—	—
Fort Nelson (1)	6.3	4.4	5.0	—	—
Fort St. John (1)	6.0	6.0	5.8	—	—
Kamloops	—	—	—	—	—
Kelowna (1)	3.4	3.0	—	—	—
Kitimat	—	—	12.0	—	13.7 e (12.4)e
Nanoose	—	—	—	7.9 (6.2)	7.4 e (5.9)e
Pender Island	—	—	—	5.8 (4.4)	7.1 e (5.7)e
Port Hardy (1)	15.1 (8.0)	15.8 (9.5)	19.4* (14.3)*	—	—
Prince George (1)	16.4	8.7	5.7	—	—
Revelstoke (1)	6.1	5.8	6.1	—	—
Sechelt	—	—	—	7.9 (7.1)	8.0 e (7.3)e
Smithers	—	—	2.3	—	—
Spectacle Lake	—	—	—	4.7 (3.5)e	—
Squamish	—	—	—	17.7 (16.4)	18.7 e (16.4)e
Terrace (1)	4.5 (4.2)	4.4 (4.1)	8.3 (7.9)	—	—
Vancouver (1)	22.2 (19.9)	22.4 (20.4)	—	—	—
Victoria	—	—	18.7	10.9 (8.4)	20.3 e (17.1)e

Table 2. Annual Deposition of Sulphate at Sampling Stations in Alberta

STATION	Annual Deposition of Sulphate ($SO_4^=$) kilograms per hectare			
YEAR	1982	1983	1984	1985
Beaverlodge	4.6	6.3	5.3	—
Calgary	9.9	8.4	7.4	—
Coronation (1)	—	5.8	—	—
Edmonton	7.5	5.9	11.0	—
Edson (1)	9.6	7.8	—	—
Fort McMurray (1)	9.6	7.1	10.8	—
Lethbridge (1)	7.3	7.7	—	—
Red Deer	7.3	5.9	7.7	—
Rocky Mountain House (1)	10.7	9.3	12.6	—
Suffield	3.3	4.7	4.2	—
Whitecourt	11.7	9.9	16.9	—

Table 3. Annual Deposition of Sulphate at Sampling Stations in Saskatchewan

STATION	Annual Deposition of Sulphate ($SO_4^=$) kilograms per hectare			
YEAR	1982	1983	1984	1985
Cluff Lake	2.1	1.8	3.9	2.0
Cree Lake (1)	3.9	—	—	—
Cree Lake (2)	—	—	4.3	2.6
Dreaver Lake	2.0	2.6	2.3	2.8
Kane Lake	2.6	2.0	3.2	3.6
Kindersley (1)	15.4	—	—	—
Lloyd Lake	—	3.2	—	1.9
Stoney Rapids	0.9	0.8	1.7	—
Wynyard (1)	9.2	10.2	—	—
Pelican Narrows	—	—	—	1.2

Table 4. Annual Deposition of Sulphate at Sampling Stations in Manitoba

STATION	Annual Deposition of Sulphate ($SO_4^{=}$) kilograms per hectare				
YEAR	1982	1983	1984	1985	1986
Bissett (1)	7.9	—	—	—	—
Brochet (3)	—	—	6.0	2.8	3.4
Dauphin (1)	13.3	—	—	—	—
Gillam (3)	—	—	5.8	3.9	3.4
Island Lake (2)	—	—	4.8	—	—
Island Lake (3)	8.7	7.7	4.9	3.7	3.3
McCreary (2)	—	—	6.2	—	—
Norway House (3)	7.2	8.2	6.0	4.1	4.2
Pointe du Bois (3)	—	—	5.6	9.1	4.5
The Pas (1)	7.3	—	—	—	—
Winnipeg (3)	—	—	—	—	5.4

Table 5. Annual Deposition of Sulphate at Sampling Stations in the Northwest Territories and in the Yukon

STATION	Annual Deposition of Sulphate ($SO_4^{=}$) kilograms per hectare			
YEAR	1982	1983	1984	1985
NORTHWEST TERRITORIES				
Fort Reliance (1)	2.6	—	—	—
Hay River (1)	3.4	5.8	—	—
Inuvik (1)	5.0	—	—	—
Mould Bay (1)	4.9	—	—	—
YUKON TERRITORIES				
Whitehorse	3.1	2.7	2.1	—

11. ADDRESSES FOR FURTHER INFORMATION

BRITISH COLUMBIA

Ministry of Environment and Parks
Parliament Buildings
Victoria, British Columbia
V8V 1X5

Concord Scientific
2 Tippet Road
Toronto, Ontario
M3H 2V2

Department of Biosciences
Simon Fraser University
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2075 Wesbrook Mall
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Department of Statistics
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University of British Columbia
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Environmental Laboratory
Ministry of Environment and Parks
3650 Wesbrook Mall
Vancouver, British Columbia
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ESSA Environmental and Social Systems Analysts
#705-808 Nelson Street
Vancouver, British Columbia
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Institute of Animal Resource Ecology
2204 Main Mall
University of British Columbia
Vancouver, British Columbia
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6th Floor, Oxbridge Place
9820-106 Street
Edmonton, Alberta
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Alberta Environment
Research Management Division
14th Floor, Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta
T5J 3N4

Alberta Environment
Technical Development Branch
Earth Sciences Division
P.O. Box 3014
Cousins Building
Lethbridge, Alberta
T1J 4B3

Alberta Environmental Centre
Environmental Technology Wing
Bag 4000
Vegreville, Alberta
T0B 4L0

Alberta Environmental Centre
Toxicology Group
Animal Sciences Wing
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Canadian Petroleum Association
1500-633 Sixth Avenue, S.W.
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Inco Ltd.
Director
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Manitoba Division
Thompson, Manitoba
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Manitoba Environment and
Workplace Safety and Health
Environmental Standards and Studies
Box 7, Building 2
139 Tuxedo Avenue
Winnipeg, Manitoba
R3N 0H6

NORTHWEST TERRITORIES

Pollution Control Division
Renewable Resources
Government of the Northwest Territories
Yellowknife, Northwest Territories
X1A 2L9

Wildlife Service
Renewable Resources
Government of the Northwest Territories
Yellowknife, Northwest Territories
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SASKATCHEWAN

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University of Saskatchewan
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Eldor Mines
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Saskatoon, Saskatchewan
S7K 3X7

Inland Waters Directorate
1st Floor, Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 3R4

Saskatchewan Environment
Walter Scott Building
3085 Albert Street
Regina, Saskatchewan
S4S 0B1

Institute of Pedology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0W0

Saskatchewan Power Corporation
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

Saskatchewan Research Council
15 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 2X8

FEDERAL AGENCIES

ALBERTA (Federal)

Canadian Wildlife Service
Environment Canada
2nd Floor
4999 - 98th Avenue
Edmonton, Alberta
T6B 2X3

Environmental Protection
Western and Northern Region
Conservation and Protection
Environment Canada
2nd Floor, Twin Atria #2
4999-98 Avenue
Edmonton, Alberta
T6B 2X3

Northern Forestry Centre
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Scientific Services Division
Western Region
Atmospheric Environment Service
2nd Floor
Twin Atria Building
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Edmonton, Alberta
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BRITISH COLUMBIA (Federal)

Environmental Protection
Pacific and Yukon Region
Conservation and Protection
Environment Canada
3rd Floor, Kapilano 100
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West Vancouver, British Columbia
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Fisheries and Oceans Canada
Fisheries - Pacific Region
1090 West Pender Street
Vancouver, British Columbia
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Scientific Services Division
Pacific Region
Atmospheric Environment Service
700-1200 West 73rd Avenue
Vancouver, British Columbia
V6P 6H9

Institute of Ocean Sciences
9860 West Saanich Road
Box 6000
Sidney, British Columbia
V8L 4B2

Pacific Forestry Centre
Canadian Forestry Service
506 West Burnside Road
Victoria, British Columbia
V8Z 1M5

Scientific Services Division
Pacific Region
Atmospheric Environment Service
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MANITOBA (Federal)

Freshwater Institute
Department of Fisheries and Oceans
501 University Crescent
Winnipeg, Manitoba
R3T 2N6

Scientific Services Division
Central Region
Atmospheric Environment Service
266 Graham Avenue
10th Floor, Room 1000
Winnipeg, Manitoba
R3C 3V4

NORTHWEST TERRITORIES (Federal)

Inland Waters/Lands
Environment Canada
Box 2970
Yellowknife, NWT
X1A 2R2

ONTARIO (Federal)

Atmospheric Research Directorate
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

Health and Welfare Canada
Brooke Claxton Building
Ottawa, Ontario
K1A 0K9

LRTAP Liaison Office
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SASKATCHEWAN (Federal)

Inland Waters/Land
Western and Northern Region
Conservation and Protection
1st Floor, Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 3R4

Scientific Services Division
Central Region
Atmospheric Environment Service
Airport Terminal Building
Box 4800
Regina, Saskatchewan
S4P 3W5

12. GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ADRP — Acid Deposition Research Programme (Alberta)

ARNEWS — Acid Rain National Early Warning System

CANSAP — Canadian Network for Sampling Precipitation

CAPMON — Canadian Air and Precipitation Monitoring Network

EPA — Environmental Protection Agency (U.S.)

EPRI — Electric Power Research Institute

$kg \cdot ha^{-1} \cdot yr^{-1}$ — kilograms per hectare per year

LRTAP — Long-Range Transport of Air Pollutants

RMCC — Research and Monitoring Co-ordinating Committee

SIMS — Societal Institute for the Mathematical Sciences

SO_2 — Sulphur dioxide

NO_x — Nitrous oxides

ZAPS — Zonal Air Pollution System

13. PRIORITIES FOR CO-ORDINATED RESEARCH AND MONITORING (1985-1988)

In September 1985 the governments of British Columbia, Alberta, Saskatchewan, Manitoba, the Northwest Territories, and Canada signed a second three-year Western and Northern Canada Acid Deposition/LRTAP agreement. The new agreement will cover the period 1985 to 1988, and will address the following eight priorities:

1. Deposition monitoring (including snowpack surveys)

This program was implemented during the initial three years of co-ordinated effort, and will continue together with the regular update of emissions inventories. This information will serve as an indicator of any deteriorating changes.

2. Deposition criteria for Western and Northern Canada

It is apparent that the target loading of 20 kilograms per hectare per year ($kg \cdot ha^{-1} \cdot yr^{-1}$) of wet sulphate used in Eastern Canada may not be appropriate for Western and Northern Canada. In Eastern Canada deposition rates are above 20 $kg \cdot ha^{-1} \cdot yr^{-1}$ at many receptor points and several sensitive ecosystems already show signs of deterioration. The target loading of 20 $kg \cdot ha^{-1} \cdot yr^{-1}$ is intended to protect at least the moderately sensitive aquatic ecosystems. In Western and Northern Canada sensitive aquatic ecosystems are not damaged yet and the deposition rates are generally below 20 $kg \cdot ha^{-1} \cdot yr^{-1}$. The relative importance of dry deposition and total acid loading criteria are of concern; therefore, target loadings for Western Canada should be developed.

3. Medium-range transport-deposition model

The Atmospheric Environment Service trajectory and deposition model, which has been applied in Western Canada, did not provide sufficient information for making management decisions. A medium-range model on a smaller grid scale is required to better characterize the situation. The long-range transport of air pollutants is less critical in Western and Northern Canada than in Eastern Canada, and receptor points are mainly affected by local sources.

4. Background sulphate ion concentrations and the role of dust

The precipitation chemistry over Western and Northern Canada is different from that over Eastern Canada. The difference in climate is a factor, and the role played by dust may be important in characterizing the precipitation chemistry. It is expected that these studies will assist in evaluating the respective contributions to acid depositions from man-made sources, as well as local and background sources.

5. Role of dry deposition

The amount of dry deposition relative to total deposition is not known for Western and Northern Canada. This will be studied to assist in determining deposition criteria. Monitoring programs and modelling studies will be developed.

6. Monitoring surface water and terrestrial environmental quality

This program is an extension of the one that began in the initial 1982 to 1985 period. The information is needed to fill in gaps in the assessment of potential sensitivity to acid deposition. Identification of long-term trends is important.

7. Impacts in highly sensitive zones

Field studies will be carried out to investigate the impacts on aquatic and terrestrial ecosystems in areas where sulphate loadings are high and in sensitive areas identified through the sensitivity mapping carried out over the past three years.

8. Control technology research methods and strategy options

The technology to control emissions is being reviewed by the Environmental Protection Service. This task will be continued with the aim of assessing the applicability of new control technologies to Western and Northern Canada. Strategy models that provide control options are currently in existence (e.g., the Ontario Model). These will be assessed in terms of their applicability to Western and Northern Canada.

Each agency has undertaken projects to address these priorities. Annual reports and copies of the 1985 to 1988 research and monitoring program are available from the participating agencies.